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The Effect of Recurrent Selection on Fiber Strength in an Interspecific Cross of Cotton.

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THE EFFECT OF RECURRENT SELECTION ON FIBER STRENGTH IN AN INTERSPECIFIC CROSS OF COTTON

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ABSTRACT

The study was made to determine the effect of recurrent selection in cotton on high fiber strength in the interspecific hybrid of Sea Island (Gossypium barbadense) and Deltapine 15 (G. hirsutum). The Sea Island parent has very high strength while Deltapine 15 is low. The materials consisted of intercrosses among 8 F_3 lines, assigned identifying numbers 13-20 for the study, which had been selected for high strength. Twenty of the 28 possible line combinations were available. Data for the original parents, the 8 F_3 lines and their F_4 selfed progenies were also obtained. Strength was determined of individual plants with the Pressley strength tester at 1/8-inch gauge.

The 8 F_3 lines differed widely in mean fiber strength as lines. Lines 13 and 16 were low in strength, lines 14 and 20 were low to intermediate, line 17 was intermediate, lines 15 and 19 were moderately high and line 18 was moderately high to high in 3 years of evaluation.

For convenience, all hybrid plants derived from crosses between any 2 lines were given the designation intercross population, while the plants derived from a single cross between 2 F_3 plants were designated as intercross progeny. The 20 intercross populations in the study varied widely in mean fiber strength, with some, such as 13 x 15, being inferior and others, such as 18 x 19, being superior. In general performance as

parents in intercrosses, line 13 was inferior, lines 14, 15, 16, 17 and 20 were intermediate and lines 18 and 19 produced high strength progenies. Thus, there was reasonably close agreement between performance as lines and as parents in intercrosses for the 8 lines studied.

Fifty-four per cent of the 84 intercross progenies tested appeared to have potential value for obtaining lines with the strength of Sea Island through selection. Consequently, it was concluded that one cycle of recurrent selection had been effective. Most of these high strength intercross progenies showed enough genetic variation to make improvement by further selection within progenies feasible.

Eight of the intercross progenies and part of the selfed progenies from F_3 parent plants contained a few plants with abnormally high fiber strength, exceeding that of the highest plant of Sea Island. No explanation for occurrence of these plants was found. Their potential in the breeding program was uncertain.

Wide mean strength differences among intercross progenies of the same intercross population were found.

All F_3 parent strength combinations, except low x low, gave 1 or more intercross progenies with high mean strength. There was a tendency for the relative frequency of high strength progenies to increase with increase in strength of the F_3 parent plants. Crosses with at least 1 intermediate or moderately high strength parent gave an intermediate frequency of high strength progenies. Crosses which had at least 1 high strength parent gave the highest percentage of high strength progenies. In order to determine more exactly the relationship between strength of the F_3 parent plants and of their intercross progenies, both were divided into the strength classes low, intermediate, moderately high and high. The low x low and low x intermediate parent combinations gave a low frequency of superior progenies. The high x intermediate, high x moderately high and high x high produced 50% or more of superior progenies. The remainder of the parent combinations produced 30-40% superior progenies. There was a marked tendency for all parent combinations to produce an unexpectedly high frequency of superior progenies.

INTRODUCTION

In recent years the cotton textile industry has experienced increasing competition from synthetic fibers. Although synthetic yarns have been found to be superior to cotton yarns in some cases, this superiority has been limited to only a very few characteristics. Synthetic fiber competition with cotton has been of two distinct types. The fibers of one type compete successfully because they are cheaper than cotton. These include the man-made cellulose fibers, rayon and acetate. A second type of fibers which offers special competition includes nylon, dacron, orlon and other such fibers. Although these are considerably more expensive than cotton, they possess some special qualities, one of which is extra high strength. Improving the strength of cotton fiber would tend to render cotton more competitive with this second type of synthetic fibers.

The strength of cotton fiber may be slightly modified by cultural changes or changes in environment, but the amount of change needed can be accomplished only through breeding for superior strength. The cotton breeder is concerned with quality as well as quantity of fiber. Improving fiber strength is primarily a genetic problem, but yield is greatly influenced by environment.

The textile industry generally considers the Upland cottons grown in the Southeast to be somewhat inferior in fiber strength. Although there is agreement that southeastern Upland cottons could be improved by increasing the fiber strength, opinions differ as to the amount of strength increase that is desired. This would be determined by the textile manufacturer and the end product which he produces. Fiber strength and yarn strength are closely associated, approximately 88% of yarn strength being accounted for by fiber strength. It is generally agreed that the best method of improving yarn strength is to improve fiber strength.

Compared to the cottons grown in the irrigated Southwest, the cotton of the southeastern United States is relatively weak, or low in fiber strength. At the present time cotton price is determined by grade and staple, with little, if any, premium being paid for high strength. For this reason farmers have not demanded high strength in the cotton they grow. Consequently, cotton breeders have not established high strength varieties adapted to the Southeast.

Three known sources of high fiber strength are available to breeders. These are _Gossypium hirsutum_ var. _punctatum_ L., or Hopi cotton from the Hopi Indians of Arizona; _G. barbadense_ L., the Sea Island and American-Egyptian varieties especially; and the tri-species hybrids involving the cultivated Asian species, _G. arboreum_ L., the American wild species, _G. thurberi_ Tod., and Upland cotton, _G. hirsutum_. In this complex situation, the two diploid species are crossed, the F_1 is treated with colchicine in order to double the chromosome number, and then this tetraploid F_1 is crossed with Upland.

A hybridization program has been initiated at the Louisiana Agricultural Experiment Station in an effort to transfer the genes for superior strength of Sea Island into Upland cotton. One phase of this program employs the recurrent selection breeding procedure in an effort to combine high fiber strength with earliness, high lint percentage and large boll size of Upland cotton.

Recurrent selection is used to concentrate genes for a particular quantitative character in a population without a marked loss of genetic variability. The recurrent selection method of breeding consists of making a cross between the parents involved and growing the F_1 and F_2 generations. As many F_2 plants should be grown as can be effectively evaluated. Desirable F_2 plants are selected in this population. Selection is made for the characters for which it can be practiced effectively. Eight or ten superior F_2 plants are selected, and the following year F_3 lines are grown from them. The F_3 lines are then intercrossed in all possible combinations. The following year a progeny of each intercross is grown. The plants within each intercross progeny are identified according to the intercross from which they came. The individual plants within each intercross progeny are evaluated as in the F_2 population. Intercross progenies which do not possess a high frequency of superior genotypes are discarded. Selected plants from each intercross may be used to begin another cycle of recurrent selection, using the same procedure which was followed in the first cycle. This process may be repeated as long as improvement is shown in the characteristics being selected.

Genetic studies indicate that the inheritance of cotton fiber strength is quantitative in nature and conditioned by a relatively small number of genes. A slight degree of dominance for weak fiber was found in intervarietal crosses. The interspecific cross which was used in the study reported herein showed absence of dominance at the 1/8-inch gauge. It was anticipated that fiber strength in this particular cross might be effectively increased by the use of recurrent selection.

There has been no report of the use of recurrent selection in cotton breeding using the interspecific hybrid Sea Island x Deltapine 15 as parents. The results of the fiber strength phase of the first cycle of this recurrent selection investigation are reported in this dissertation.

REVIEW OF LITERATURE

Fiber Strength

As early as 1912 McClendon (28) reported that weak fiber was dominant over strong fiber in a cross between American Upland and Sea Island cotton. The Upland varieties used in the crosses included Cook's Big Boll, Sistrunk, Pride of Georgia, Hasting's Big Boll and Toole. As the strength determinations were made by hand, only "weak" and "strong" classes were considered.

Balls (2) stated in 1919 that methods for determining the strength of small samples of cotton fiber were nonexistant. It was possible at that time to measure breaking strains, but to obtain sufficient results to give a reasonable probable error for only a single seed involved an enormous amount of labor. He stated when large numbers of seed have to be examined, the method becomes hopeless.

He concluded that the thickening of the cell wall determines the strength of the individual fiber. The strength of the commercial sample depends on wall thickness and uniformity of strength as between different fibers, also on uniformity of that thickness over the whole length of the fiber.

Kearney (23) worked with the F_2 and F_3 generations of a cross between the Holden (G. hirsutum) and Pima (G. barbadense) cotton varieties. His objective was to obtain statistical data on the nature and behavior of variants to be expected in cotton fields of either species as a result of natural cross-fertilization. This information was to be used by workers in rogueing seed increase fields. His chief concern was with the botanical characters of the plants. Fiber properties were not measured, due to the lack of means of doing so. He did make some observations concerning fertility and the level of productivity of the segregating populations. He noted that while the F_1 of the Holden x Pima cross was extremely fertile, 7% of the 215 F_2 plants showed "absolute sterility" and that a low degree of fertility was common. Many seed from the F_2 plants had low viability which caused the loss of a considerable number of seedlings among the F_3 progenies. Although each hill contained 3 or 4 seeds, in approximately 25% of them no plant grew beyond the seedling stage.

Concerning the fertility of the segregating generations, Ware (39) reached the same conclusions as Kearney (23). He obtained little reliable data on F_3 plants of 3 crosses of _G. hirsutum_ x _G. barbadense._ He did not report any study of inheritance of fiber strength.

Working at the Arizona Agricultural Experiment Station, Pressley (31) designed a tester for measuring the strength of cotton fibers. With the Pressley strength tester, strength determinations were made on the basis of the number of pounds of force required to break 1 milligram of cotton fibers cut to the width of the clamps used in breaking the fiber, or 0.464 inch. This value, the number of pounds required to break 1 milligram of cotton fibers cut to the standard length, became known as the Pressley index.

Moore (29) made strength measurements of individual fibers, calculating the breaking load with a machine of the balance type. The breaking load, which was applied to the 3/8-inch mid-portion of the fiber, was added to the beam at the rate of 1/10 gram per second. It was recorded to the nearest 0.01 gram. The fibers were taken from 6 different regions of individual seeds from 5 varieties of Upland cotton. There was considerable variation among fibers taken from different regions on the seeds. The strongest fibers were found to be on the micropylar end of the seed while the weakest fibers were found on the chalazal end.

Hancock (10) conducted an experiment to determine differences among cotton varieties in their expression of lint strength and to consider the influence of environment on this character. He grew 10 varieties of American Upland cotton in 3 locations having different soil types. Strength was measured with the Pressley strength tester at "0" gauge. This was the first report of the use of this instrument for strength measurements. He found large differences between individual plants within a variety, as well as differences between varieties. He indicated that strength seemed to be sensitive to small differences in soil in some of the tests.

Ware and Harrell (40) grew F_1, F_2, F_3, and 2 generations of backcrosses to each parent, of a cross between the 2 Upland cotton varieties, Florida Green Seed and Rowden. Fiber strength was measured with the

Pressley strength tester at "0" gauge. This was the first report of the use of this instrument in a genetic study. The parents differed by approximately 1.0 Pressley index unit, the Florida Green Seed being the stronger of the 2 varieties. The results were variable, but in general indicated that the inheritance of fiber strength was quantitative in nature with the F_1 being intermediate. There was a slight degree of dominance for weak fiber. The mean of the 87 F_2 plants was slightly above the median point between the 2 parental means. The F_3 progenies were more variable than either parent, but the means of the F_3 lines tended to maintain the level of the F_2 plants from which the lines originated. Season affected strength to some degree.

Barre (3) reported that there is sufficient evidence that the special structure of crystalline cellulose in the central layers of the cotton fiber largely determine its tensile strength. Although this structure and the average dimensions of the fiber may be modified by environment, further studies showed them to be distinct varietal characteristics. He stated that while the variety grown was the most important single factor in determining fiber strength and other properties, deviation from the ideal environment modified the inherent fiber properties. Spiral structure was not affected by bad harvest weather conditions that were invariably reflected in impaired strength.

Hancock (11) studied strength and other fiber properties in relation to plant structure and growth period. Bolls from which measurements were made were designated as to plant, node number and date of flowering. Three Upland varieties in replicated plots at 2 locations were used. The strength was measured with the Pressley strength tester at "0" gauge. Fiber from bolls produced at different nodes showed no significant difference in strength. The period producing the strongest lint seemed to vary with the variety and the location. Two varieties had stronger lint in the first of the 3 flowering periods than the third while the third variety had the strongest lint in the last period. Large variations in strength were found between bolls on the same plant, between plants and between groups of plants. He stated that 3 pickings of cotton were justified for accurate sampling by an agronomist and at least 4 bolls should be harvested from the middle of the plant by the breeder.

Kime and Tilley (24) studied the effect of hybridization on the yield, fiber strength and 10 other characters of F_1 and later generations from 6 crosses between inbred lines selected from Coker 100, Stoneville and Deltapine 11A varieties of Upland cotton. Fiber strength was measured for 1 year, using the Pressley strength tester at "0" gauge. The mean strength of the F_1 generation of all crosses was intermediate between the parents.

In a study of hybrid vigor Simpson (34) made strength determinations for plants grown from seed from 2 different sources. The first source, which was designated as "inbred" seed, consisted of seed from 7 varieties grown in isolated fields. The second source, designated as "crossed" seed, came from seed from open-pollinated plants of the same varieties grown in a variety test. Strength measurements were made with the Pressley strength tester at "0" gauge. There were no significant differences in strength of fiber from the 2 seed sources. There was an apparent tendency for the lint from crossed lots of the weaker varieties to be stronger than the inbred parent, but the data were inconclusive.

In a collection of about 400 strains of Upland cotton maintained by the Mississippi Agricultural Experiment Station, Green (9) found that the lint strength ranged from 4.75 to 9.75 Pressley index units. Strength determinations were made with the Pressley strength tester at "0" gauge. He pointed out that strength was affected more by location in the field than any other fiber property he discussed. The 5 local varieties used as controls were found to have become stabilized near the mean of the entire sample. The range observed indicated the presence of an important amount of genetic variability.

Gonzales (8) studied the inheritance of strength in the F_2 generation of a cross between 2 varieties of American Upland cotton. The parental varieties were Delfos 9169 and (A x B)293, the latter being a selection from an F_4 of a Wilds x Half and Half cross. Fiber strength was measured with the Pressley strength tester at "0" gauge. There was very little difference in fiber strength of the parents, and wide variations occurred within each parent. The F_2 showed a normal curve which is characteristic of quantitative characters. He concluded that the mode of inheritance was quantitative in nature and conditioned by multiple factors.

Isaac (16) studied the F_2 of a cross between Stoneville and Delta Smooth Leaf, both of which had similar Pressley indexes. He measured fiber strength with a Pressley strength tester at "0" gauge. He found that the F_2 population exhibited a unimodal curve which was skewed slightly toward the weak side. He concluded that his results were similar to the frequency distributions obtained with most quantitative characters showing inheritance characteristic of multiple factors.

Richmond and Lewis (32) conducted an experiment designed to compare the performance of stocks grown from seed mixtures of cultivated American Upland cotton varieties with the performance of the component varieties grown as pure stocks. All of the mixtures gave higher strength values than those obtained from the weighted means of the corresponding pure stocks. Two of the mixtures were significantly higher. They offered the possible explanation that more efficient mixing of fibers might be expected as a result of growing mixtures rather than attempting to mix fibers of pure stocks after ginning.

Stafford (38) studied the inheritance of fiber strength and perimeter in an intervarietal cross of Wilds x Half and Half. Strength determinations were made with the Pressley strength tester at "0" gauge. He found that the mean Pressley index of the F_1 and F_2 was slightly below the arithmetic average of the parents and concluded that this indicated partial dominance of weak fibers. No conclusions were drawn concerning the nature of gene action. The parental difference in fiber strength appeared to be conditioned by a small number of genes, probably 3 or 4 pairs. F_3 results were found to be more reliable than the formula used with the F_2 population to estimate heritability. Estimates of heritability based on F_3 data indicated that it would be advisable for a breeder to select rigidly in a large population in order to insure selection of an adequate number of superior plants.

Self and Henderson (33) investigated the inheritance of fiber strength in a cross of AHA 50 and Half and Half. The strength determinations were made with the Pressley strength tester at "0" gauge. They found the F_1 mean of 8.2 Pressley index units to be slightly lower than the parental average. This was essentially intermediate between the parental means of 9.8 and 7.1, respectively. In the F_2 population of 806 plants the range was continuous from 6.6 to 9.9 units Pressley index. The F_3 lines were planted in a randomized block design with 3 replications. Fiber strength obviously was inherited as a quantitative character. The Castle-Wright formula for estimating the number of genes gave an estimate of 5 pairs. The F_3 lines originated from 66 F_2 plants representing the complete F_2 strength range. As a particular effort was made to include a comparatively large number of plants within each of the parental ranges, the F_3 lines were not derived from randomly selected plants.

Progeny tests of the F_3 indicated that among the 806 F_2 plants there was a probable recovery of 1 or more plants representative of each parent genotype. In view of the frequency of recovery of parental genotypes in F_2, they felt that 4 would be a more probable estimate of the gene number differentiating the parents.

Burley and Carpenter (4) studied the relation between fiber strength and yarn strength. They used 75 samples of cotton which included a wide range of fiber and spinning properties. Gauge lengths of "0", 2, 3 and 4 mm. were used with the Pressley and the Clemson testers. Simple correlation analyses were made using the strength-weight ratios as dependent variables with strength of 22s carded yarn as the dependent variable. The $\bar{r}$ values for the 3 mm. gauge spacing were consistently higher than for any other gauge spacing. A curve fitted to the $\bar{r}$ values for the various gauge spacings indicated that a maximum relationship would be found just beyond the 3 mm. gauge spacing or, approximately at 1/8 inch (3.2 mm.) gauge spacing.

Pressley tests at "0" and at 1/8 inch gauge lengths were made on 323 cotton samples selected as representative of the commercial crop of the United States in 1954. Simple correlation analyses of fiber strength with strength of 22s carded yarn gave r values of 0.229 and 0.805 for the "0" and the 1/8 inch gauge length, respectively. They concluded that for predicting or explaining 22s carded yarn skein strength the test results from the same samples would be much more valuable using the

1/8 inch gauge spacing than the "0" gauge.

An allotetraploid between 2 thirteen-chromosome species, G. arboreum and G. thurberi, was crossed with the cultivated tetraploid, G. hirsutum, by Lewis (25) to produce an allotetraploid involving 3 species of Gossypium. The F_2 and F_3 progenies were extremely variable in plant habit, seed cotton production, and in all lint properties. Lint strength determinations were made with the Pressley strength tester at "0" gauge. Lewis indicated that there is an opportunity to develop from this material new combinations of lint length, strength and fineness which should be stabilized into relatively true breeding stocks and later used in a breeding program to improve the quality of cotton. He found a highly significant correlation of 0.562 between F_2 and F_3 progenies for lint fiber strength.

Al-Jibouri, Miller, and Robinson (1) grew a population of F_3 progenies from a cross between a high lint strength but low yielding strain from the tri-species hybrid arborium-thurberi-hirsutum and an adapted strain of Upland cotton. Strength determinations were made with the Stelometer at 1/8-inch gauge. Their predicted effects of selection indicated it would be very difficult to obtain the desired character combinations of high yield and lint percentage with high lint strength from this population.

Worley (41) studied the inheritance of strength in an interspecific cross between Deltapine 15, G. hirsutum, and Sea Island, G. barbadense. Fiber strength was measured with the Pressley strength tester at 1/8-inch gauge. He found that fiber strength behaved as a quantitative character and showed absence of dominance at 0.125 strength index. Estimates indicated that fiber strength was conditioned by a relatively small number of genes.

Recurrent Selection

Hayes and Garber (14) suggested the use of certain principles of the recurrent selection method of breeding. The objective of an experiment they initiated at the Minnesota Agricultural Experiment Station in 1915 was to produce a high protein strain of corn from the Minn. 13 variety. The method was to self-fertilize a number of ears and analyze them for protein content. The high protein self-fertilized ears were then used as parents. The plan was to isolate a number of high protein strains and then determine which produced the highest yields in crosses. The best yielding cross was then to be planted in an isolated plot and selected for vigor. Two strains were isolated which gave a much higher percentage of protein than normal pollinated corn. The 2 strains were crossed in 1917 and individual rows were grown in 1918. A bulk analysis showed that the protein content of the 2 crosses was on the average a little over 2% higher than normal pollinated Minn. 13. It was concluded that the application of these principles offered almost unlimited opportunities to improve corn.

East and Jones (7) used certain principles of the recurrent selection method of breeding in an effort to obtain high protein strains of corn.

The procedure was simply to cross different selected high protein lines, to self-pollinate the first generation plants, and to select again from the progenies which represent segregating populations. They concluded that a high percentage of protein may be produced with certainty and rapidity by this method.

Jenkins (17) was the first to publish a detailed description of the recurrent selection method of breeding. Data collected previously, in connection with the procedure outlined by the author, suggested that inbred lines of corn became stable for yield prepotency early in the inbreeding period. Therefore, the author suggested the possibility of producing synthetic varieties among short-time inbred lines to use in sections where hybrid corn might not be economically feasible. The essential steps of the procedure are as follows:

1. The isolation of one-generation selfed lines.

2. Testing of these lines in top-crosses for yield and other characters to determine their relative endowments with respect to genes affecting these characters.

3. Intercrossing of the better endowed selfed lines to produce a synthetic variety.

4. Repetition of the above process at intervals after each "synthetic variety" has had a generation or two of mixing, possibly with the inclusion of lines from unrelated sources.

In 1945 Hull (15) outlined a procedure which he called recurrent selection--the first use of the term--for specific combining ability. His procedure differed in principle from that of Jenkins (17) only in substituting an inbred tester for a heterozygous tester. Thus, Hull's plan consisted essentially of recurrent selection in a crossbred lot of corn for combining ability (high yield) with a single homozygous line which may be called the tester. The crossbred lot may be a common variety, a cross of varieties, or a cross of superior inbred lines. The breeding procedure as outlined by Hull is as follows:

First Year--Select at random with respect to evidence of inherent vigor 100 plants or more in the crossbred lot. Self-pollinate these plants and use pollen from each one separately on the silks of the tester line.

Second Year--Record the yield performance of the 100 test hybrids.

Third Year--Grow ear-rows from selfed seed of 10 or more plants which had the higher yielding test hybrids and make numerous crosses between but not within the rows.

One cycle of recurrent selection is completed in 3 years. The next cycle begins with bulked intercrossed seed from the last operation of the preceding cycle and the same tester line. Cycles may recur continuously.

Comstock, Robinson, and Harvey (5) outlined a procedure of breeding and selection which they called recurrent reciprocal selection. The method was designed to make use of both general and specific combining ability. Foundation material from 2 sources was used. The hybrid or hybrids developed involved crossing material descending from these 2 sources. S_0 and S_1 plants from source A were self-fertilized and at the same time were outcrossed to plants from source B. Selection was based on experimental comparison of topcross progenies and selected plants were interbred the third year using their selfed seed produced the first year. The cycle was reinstated the fourth year. Source B plants were tested against source A plants in the same manner.

They outlined a more detailed description of the method, but the only difference between the recurrent reciprocal method and Hull's (15) method is in the tester. In Hull's method all the selected material is tested against one tester. In the recurrent reciprocal method the selected material is tested against 2 different testers. It was pointed out that recurrent reciprocal selection offers potentialities for further improvement of good double crosses.

Harland (13) suggested a method of breeding which is similar to the recurrent selection method of breeding. He termed the method "mass pedigree selection." The essential steps of the method are summarized below.

1. Examine a large number of single plants from a heterozygous commercial variety. Obtain quantitative estimates of the main characters which are to be worked on and establish norms of the characters required.

2. Grow in progeny rows a large number of single plant samples which have passed preliminary tests (1 replication).

3. Examine bulked samples from the progeny rows and eliminate those lines which fail to conform to the norms set up. This may be called the bulked norm test.

4. Examine all of the single plants of the lines passing the test and eliminate plants which themselves fail to conform to the norms set up. This may be called the single plant norm test.

5. Select from this material an elite of, say, 200 plants. Grow these in progeny rows with an adequate number of replications.

6. Apply the bulk norm test to eliminate undesirable lines, and also to eliminate lines which in yield of seed cotton per plant are below the mean of the whole population of lines.

7. Mix the seed from the lines which passed the bulked norm test and institute a multiplication plot.

8. Plant the whole production of number 7 in an isolated field or large farm.

9. Plant the whole production of number 8 on a large area of the same farm.

10. Distribute the production of number 9 as the first commercial wave of seed.

11. Continue steps from 2 to 10 with such modifications as practical exegencies necessitate so that each year a new wave of seed can be distributed.

Harland employed this procedure for the production of Peruvian Tanguis cotton. The mean fiber length of the original population of a current Tanguis variety was shifted from 1 3/16" to 1 6/16" in 2 generations of mass pedigree selection. The mean of the original population for boll weight was shifted from 4.4 grams per boll to 5.0 grams per boll. The mean lint percentage was shifted from 37.0 for the original population to 40.5. Inferior strains with respect to color and fineness were eliminated.

In an experiment conducted at the U. S. Southern Great Plains Field Station at Woodward, Oklahoma, Harlan (12) chose 14 plants of side-oats grama, Bouteloua curtipendula Torr., in each of 18 different agronomic types. As a method of fixing selected characters in a population, vegetatively propagated plants in each type were allowed to intercross in isolated blocks. Considerable progress was made in fixation of some of the types after 2 successive generations of selection. Although he did not call this system recurrent selection, it does employ the basic principles of successive cycles of selection for a specific purpose among individuals in a heterozygous population and the subsequent recombination of the selected portion of the population.

Sprague and Brimhall (35) reported results from attempts to utilize recurrent selection in developing inbred lines of corn or composites having a high frequency for genes conditioning oil percentage of the grain. They desired to investigate the efficiency of the recurrent selection method of breeding in modifying the oil percentage. Their objectives were the accumulation of material having a high oil percentage and critical evaluation of the recurrent selection method of breeding. They combined these 2 objectives into a single experiment, using the standard procedure of selection within and among inbred lines as a control method.

The original material was made up of reciprocal backcrosses involving a single cross. The mean oil content of the original population was 7.2%. The mean oil percentage of the selected parents for this population was approximately 8.5%. This mean was shifted to approximately 9.6% as a result of the first cycle of recurrent selection, slightly exceeding the mean of the selected parents. They attributed this unexpected result to the vagaries of sampling.

In the population of the second cycle of recurrent selection the mean oil percentage was further shifted above that of the original population, or to 10.5% with an extreme of 13.5%.

A second population studied by Sprague and Brimhall (35) had its origin in the F_2 generation. The 10 selfed ears having the highest oil percentage in the grain were intercrossed and bulked. The mean oil percentage of the original F_2 population was approximately 4.2%. The mean oil percentage of the selected parents for this population was approximately 5.2%. The population of the first cycle of recurrent selection had a mean oil percentage of 5.3%. Parents selected for the recurrent selection population had a mean oil percentage of 5.9%. The range in the first cycle of recurrent selection was from 4.0 to 6.2%. They pointed out that in this instance the full advantage of the selected parents was retained in the first cycle of the recurrent selection population. The standard deviation for the first cycle was greater than for the F_2 population.

They concluded that, at the end of the 5 year period and under the conditions of the experiment, the recurrent selection procedure was 2.6 times more efficient than selection during inbreeding. It would be expected to increase in relative efficiency as the time period increased.

Lonnquist (26) used the recurrent selection method of breeding in corn to determine whether the frequency of favorable growth genes in a heterozygous population might be increased. If this could be done prior to the extraction of the inbred lines, the chances of isolating superior genotypes for combining ability would be increased.

The method consisted of recurring cycles of selfing and top-crossing S_0 plants in a heterozygous population. A composite of selfed seed of the highest yielding S_0 plants as determined by their top-cross performance was allowed to intercross at random for several generations before initiating the next cycle. The method appeared to provide greater efficiency in the selection of superior genotypes and a higher level of combining ability in the lines obtained.

At the Iowa Agricultural Experiment Station, Sprague, Miller, and Brimhall (36) tested the relative effectiveness of recurrent selection versus selection in selfed lines in increasing the oil percentage of the corn kernel. A synthetic variety provided the parent material.

In order to obtain the recurrent selection series, they selfed 100 shoots and at harvest time analyzed the selfed ears for their grain oil percentage. The 10 ears having the highest grain oil percentage were selected and grown in ear-to-row progenies. The progenies were then crossed in all possible combinations. An equal quantity of seed was selected from each combination at harvest time and bulked. The bulked population was selfed. At harvest time 100 selfed ears from the bulked population were analyzed for their grain oil content. As before, the 10 ears having the highest grain oil content were grown in ear-to-row progenies and intercrossed. This provided 2 cycles of recurrent selection.

The selfing series was obtained by using remnant seed from the 10 original ears which were selected for the recurrent selection series. The selfed ears were grown in ear-to-row progenies, and the plants within each progeny were intercrossed. Five ears from each progeny were analyzed for their grain oil percentage at harvest time. The progenies having the lowest mean oil percentage were discarded and those having the highest mean oil percentage were saved to propagate the strain. This process continued for 5 generations.

A striking feature of the results was the marked shift in the mean oil percentage. For the original population the mean oil percentage was 4.2, but the first cycle of recurrent selection shifted it to 5.2. The second cycle of recurrent selection shifted the mean to 7.0%. The mean oil percentage for the selfing series was increased from 4.97 for the S_1 generation to 5.62 for the S_5 generation, an average of 0.13% increase per year.

They concluded that the recurrent selection procedure was more effective than selection in selfed lines for increasing the oil percentage of the corn kernel.

Johnson (19) studied recurrent selection in biennial sweetclover, Melilotus officinalis Lam. His objectives were to determine the extent of variability in general combining ability in an unselected population of the Madrid variety and to study the effectiveness of the first cycle of recurrent selection in changing the population distribution. In general combining ability, a number of individual plants were superior to the original population. Large positive gains in a single cycle of recurrent selection were obtained, an indication that this breeding procedure may be an effective method for breeding forage crops. In reporting the results of the second cycle of recurrent selection (20) he stated that the opportunities for further genetic advance might be as great in the third as in each of the 2 previous cycles.

Johnson and Goforth (22) studied the effectiveness of controlled mass selection for lateness of flowering in biennial sweetclover. An interest was shown in measuring the rate of progress in successive generations and comparing the progenies from controlled mass selection with those from recurrent selection for general combining ability. Four generations of visual selection in the second year for desirable plants with respect to combining ability was not as effective as a single cycle of recurrent selection based on progeny performance.

Jenkins, Robert, and Findley (18) studied the effectiveness of recurrent selection as a breeding procedure for concentrating genes for resistance to Helminthosporium turcicum Pass. leaf blight in corn. Nine single crosses involving 11 inbred lines were used in the study. Three cycles of recurrent selection were practiced within each of the 9 progeny groups, providing a total of 27 comparisons. In 24 comparisons the difference between successive cycles was positive, indicating increases in resistance associated with selection. In 3 comparisons the differences were negative, indicating reductions in resistance. Sixteen of the positive differences were highly significant; three, significant; and five, not significant. The selection procedure, therefore, was highly effective. Two of the negative differences were highly significant and were not explained. The remaining one was not significant. The results obtained suggest that 2 cycles of recurrent selection were sufficiently effective to be warranted in most of the groups studied.

Newman (30) studied the effects of the first cycle of recurrent selection on gene frequency for lint percentage and fiber strength in cotton. Fiber strength was measured with the Pressley strength tester at zero gauge. He recovered a higher percentage of plants above the fiber strength means of the parents in the F_2 than in the recurrent selection population. He believed this to be due to the fact that more than half of the F_3 lines were no better than the mean of the parents. Outstanding plants in certain intercrosses were as good as, or better than, outstanding plants in the F_2. He concluded that selection would be more effective in the superior intercrosses than in the F_2 population.

McGill and Lonnquist (27) studied 3 synthetic varieties of corn which were developed by 2 cycles of recurrent selection for combining ability. Krug yellow dent corn, an open-pollinated variety, was the source material. S_0 plants in each of the 4 populations were outcrossed to WF9 x M14 and the test-crosses grown in a yield trial. It was concluded that the 2 cycles of recurrent selection had been effective in modifying combining ability and that the high-yield synthetics would be better sources of new lines than Krug. Recurrent selection was considered equal and possibly superior in efficiency to the continuous selfing method.

Johnson and El Banna (21) found that over 4 generations of recurrent selection the improvements in growth habit of sweetclover were greater than those in plant vigor. This indicates that the heritability of the former character is higher. The difference between the average yields of the selected groups of plants increased in each successive cycle and several of the S_1 lines derived from the highest yielding populations were more productive than their parental variety, Madrid. It was concluded, from the degree of progress made, that phenotypic recurrent selection was of value as a rapid and efficient method for improving cross-pollinated forage plants.

Sprague, *et al*. (37) presented yield data which indicated the effectiveness of recurrent selection for specific combining ability in corn. After 2 cycles of selection, yield increases were 6.5 bushels in the Lancaster series and 20.0 bushels in the Kolkmier series.

On the basis of mean seed weights of the top-cross seed Christie and Kalton (6) selected the 10 highest and the 10 lowest of 203 clones of bromegrass, *Bromus inermis* Leyss. These were recombined in separate isolated polycross blocks, and the polycross progenies were evaluated for seed weight in spaced plantings. The mean seed weights in grams per 300 seeds for progeny plants of the low and the high groups ranged from 0.44 to 1.29 and from 0.69 to 1.62, respectively. The mean difference between the two groups was highly significant. On the basis of estimated percentages of genotypic variance, it was concluded that further progress by recurrent selection would be feasible.

MATERIALS AND METHODS

The materials used in this investigation included the *Gossypium hirsutum* and *G. barbadense* parents, progenies of 20 of the 28 possible intercrosses among 8 selected F_3 lines, and an F_4 population consisting of the progenies of the F_3 plants which were used in the intercrosses. This material had been derived from an interspecific cross between the Deltapine 15 variety of *G. hirsutum* and the Sea Island strain of *G. barbadense* cotton. The procedures used in making the cross and in growing the F_1 and F_2 generations were reported by Worley (41).

On the basis of lint percentage and fiber strength, 51 of the F_2 plants were selected and progeny tested in the F_3 generation. Eight of these 51 lines were selected on the basis of earliness, lint percentage, boll size and fiber strength, and intercrossed in all possible combinations. Plots of the parents, F_4 progenies of plants selected from the 8 F_3 lines, and 20 of the "intercross populations" from crosses among the 8 F_3 lines were grown in 1958. The seed cotton was harvested and ginned from each individual plant.

Before the research was conducted by the writer, 8 plants had been randomly selected from each of the 8 F_3 lines for the purpose of making intercrosses. The 8 lines had been assigned the numbers 13 through 20, and each of the 8 plants in each line was tagged with an identifying number, 1 through 8. Controlled crosses had been attempted among the 8 F_3 lines in all of the 28 possible combinations, using several plants per line in each combination. The bolls resulting from the hand pollinations were harvested, put into paper bags marked with the line and plant numbers of both parents, and ginned separately.

All of these procedures had been completed by others prior to the time that the writer became associated with the research.

The parent populations were grown from seed produced on the plants which were used in making the original cross. The Deltapine 15 parent progenies came from selfed seed. Since no records were available and because of the great difficulty always encountered in getting selfed seed from Sea Island, it must be assumed that the Sea Island parent progenies came from open-pollinated seed from a plant growing in the greenhouse. The parent progenies were spaced in paired plots at 10-plot intervals throughout the entire experimental area in order to give an estimate of environmental variation. Strength determinations were made for 57 individual plants of Deltapine 15 and 67 plants of Sea Island.

In this dissertation the term "intercross progeny" refers to a group of plants grown from seed derived by crossing a single plant from one F_3 line with a single plant from another F_3 line. For example, plant 1 of line 13 was crossed with plant 3 of line 15, and 8 plants were grown from this intercross. These 8 plants constituted an intercross progeny, which was designated as 13-1 x 15-3, representing the line and plant numbers of both parents.

The term "intercross population" refers to the combined intercross progenies which were derived from any two F_3 lines. In addition to the intercross progeny 13-1 x 15-3, referred to previously, 3 others involving lines 13 and 15 were grown. These other 3 intercross progenies were 13-3 x 15-2, 13-3 x 15-5 and 13-5 x 15-2. These 4 intercross progenies, constituting an intercross population with the designation 13 x 15, contained a total of 36 plants. Each of the 20 intercross populations was designated in this manner by the 2 F_3 line numbers from which it was derived, such as 13 x 18.

Twenty intercross populations had been derived from crosses among the 8 F_3 lines. Eight of the possible intercrosses were not obtained. The 20 intercross populations, the individual F_3 plants from which each intercross population was derived and the number of plants in each intercross population are summarized in Table 1.

The number of F_3 plants per line which were involved as parents in the 20 intercrosses varied from 1 to 5. Three of the 20 intercross populations were derived from crosses in which only 1 plant was used from 1 or both of the F_3 parent lines involved. These 3 intercross populations were 13-1 x 19-1, 16-3 x 17-8 and intercrosses of plant 20-8 with 3 plants of line 17. Six of the intercross populations were derived from crosses in which 2 plants from 1 or both of the F_3 lines were used. These intercross populations were 13 x 18 , 13 x 20, 14 x 18, 15 x 16, 15 x 17, and 17 x 18. Twelve intercross populations were derived from crosses in which 3 plants were used from 1 or both of the F_3 parent lines involved. These 12

Table 1. Intercross populations, parent plants involved in these populations and number of plants per population in the study.

Intercross population	Plant numbers of the first parent		Plant numbers of the second parent	No. of plants in intercross population
13 x 15	13-1, -3, -5	x	15-2, -3, -5	36
13 x 18	13-1, -3, -5	x	18-1, -7	25
13 x 19	13-1	x	19-1	16
13 x 20	13-1, -5	x	20-3, -4, -7	35
14 x 15	14-2, -4, -5	x	15-2, -4, -5, -6	73
14 x 18	14-1, -2, -4, -5	x	18-1, -7	59
14 x 19	14-1, -4, -5	x	19-1, -2, -3, -4	81
15 x 16	15-2, -3, -6	x	16-5, -7	36
15 x 17	15-3, -5	x	17-5, -6	14
15 x 18	15-1, -3, -4, -6	x	18-1, -3, -5	42
15 x 19	15-1, -2, -3, -5, -6	x	19-1, -3, -7	81
15 x 20	15-2, -3, -4	x	20-4, -5, -8	29
16 x 17	16-3,	x	17-8	18
16 x 19	16-5, -6, -7, -8	x	19-1, -3, -5, -8	45
17 x 18	17-6, -8	x	18-5, -7	33
17 x 19	17-1, -5, -6, -8	x	19-1, -2, -3, -5, -7	96
17 x 20	17-1, -5, -8	x	20-8	39
18 x 19	18-1, -5, -7	x	19-1, -2, -3, -4, -5	72
18 x 20	18-1, -3, -5, -7, -8	x	20-3, -4, -7, -8	89
19 x 20	19-1, -2, -3, -4	x	20-2, -7, -8	104
Total				1,023

intercross populations included 13 x 15, 13 x 18, 13 x 20, 14 x 15, 14 x 19, 15 x 16, 15 x 18, 15 x 19, 15 x 20, 17 x 20, 18 x 19, and 19 x 20. Eight intercross populations were derived from crosses in which 4 plants were used from 1 or both of the F_3 parent lines involved. These intercross populations were 14 x 15, 14 x 18, 14 x 19, 15 x 18, 16 x 19, 17 x 19, 18 x 20 and 19 x 20. Four of the intercross populations were derived from crosses in which 5 plants were used from 1 of the F_3 parent lines involved. These 4 intercross populations were 15 x 19, 17 x 19, 18 x 19 and 18 x 20.

Eleven of the 20 intercross populations were derived from crosses in which 3 or more plants were used from both of the F_3 parent lines involved.

A total of 84 intercross progenies were grown and tested for fiber strength. The number of plants per intercross progeny varied from 1 plant per progeny in 18-1 x 19-5 and 18-5 x 19-5 to 24 plants in 18-8 x 20-8. Fifty-six of the intercross progenies had 10 or more plants. Only 6 of the intercross progenies had fewer than 5 plants.

Within any F_3 line the same plants were not used in all of the intercrosses involving that line. Using line 15 as an example, in intercross population 13 x 15, plants 15-2, 15-3 and 15-5 were used; while in 14 x 15, plants 15-2, 15-4, 15-5 and 15-6 were used. Plant 3 was used in 13 x 15 but not in 14 x 15, while plants 4 and 6 were used in 14 x 15 and not used in 13 x 15.

In several cases a specific plant in an F_3 line was common to all intercrosses containing that line; for example, plant 1 in line 13, plants 4 and 5 in line 14, and plant 1 in line 19. The same group of plants within an F_3 line occurred in 3 pairs of intercross populations. Plants 1, 3 and 5 of line 13 were used in intercross populations 13 x 15 and 13 x 18. Plants 1 and 7 of line 18 were involved in intercross populations 13 x 18 and 14 x 18. Plants 1, 2, 3 and 4 of line 19 occurred in intercross populations 14 x 19, 18 x 19 and 19 x 20.

Of the 8 F_3 lines only 15 and 19 were represented in all of the 7 possible line combinations. Line 18 had 6 of the possible combinations, while lines 17 and 20 had 5 combinations each. Line 13 had 4 combinations represented, and lines 14 and 16 occurred in only 3 of the 7 possible line combinations.

An F_4 progeny was grown from selfed seed of each F_3 plant from which an intercross progeny was derived. A total of 39 F_4 progenies were grown and tested for fiber strength. The plants of all of the F_4 progenies derived from each F_3 line made up the F_4 population of that particular line. The number of plants for any F_4 progeny which was tested for fiber strength varied from 1 to 24. Twenty-nine of the F_4 progenies had 10 or more plants. Only 7 of the F_4 progenies had fewer than 5 plants. The number of plants per F_4 population ranged from 27 to 94, and the total number of plants in the 8 F_4 populations was 466.

The steps followed in sampling for fiber strength determinations are summarized below.

a) Grasp the lint sample with both hands and pull apart.

b) Place both portions of the sample in one hand so that the broken ends are together.

c) Smooth the face of the sample by pulling out matted tufts of fibers.

d) Pull, with thumb and forefinger of the free hand, a random sample (bundle) of fibers from the entire face of the lint sample. Repeat the above procedure to secure a second sample (bundle).

e) Place samples of fiber in a coin envelope bearing the proper plant identification numbers and return lint samples to the original bag.

Fiber strength determinations were made on the Pressley strength tester at 1/8-inch gauge. The steps involved in making the strength measurements are given below.

a) Pull a small tuft of fibers from the end of one of the samples (bundles) which were stored in the coin envelope.

b) Pull the tuft of fibers through the comb attached to the torsion vise used with the tester. The tuft is pulled through the comb to make a parallel ribbon of fibers and to remove short, broken fibers, trash and neps. Precautions are used to comb all samples in the same manner in order to minimize bias.

c) Place combed ribbon of fibers in open clamps held in torsion vise.

d) Close clamps and tighten top screws of clamps until torsion vise starts twisting. Use of the torsion vise assures uniform tightness of the clamps.

e) Place clamps in tester and release rolling weight, allowing it to roll down the beam of the tester until the ribbon of fibers held in the clamps is broken.

f) Record, to the nearest 0.01 pound, the beam reading, which must fall between 13.50 and 19.00 pounds. Values below 13.50 are not accepted because of possible bias due to small sample size. Those above 19.00 are not accepted because of possible bias due to overshoot of the rolling weight (distance the weight travels after the ribbon of fibers breaks).

g) Remove the clamps from the tester and cut the fibers extending from the sides of clamps flush with the clamp edge, establishing the standard length of ribbon of fibers for strength determinations.

h) Place clamps in torsion vise, loosen top screws and carefully remove the broken ribbon of fibers with tweezers.

i) Place the broken ribbon of fibers on weighing arm of balance and weigh to the nearest 0.01 milligram.

j) Divide the beam reading for the ribbon break in pounds by the weight of the ribbon in milligrams. The quotient is the strength value recorded for the bundle.

k) A second strength determination is made as outlined in steps (a) through (j), utilizing the remaining bundle of fibers in the coin envelope. These 2 determinations are averaged to establish the strength value of the plant if they are within a specified strength tolerance. The tolerance is 0.15 pounds per milligram. In cases where the tolerance is exceeded, an additional break is made and the 3 breaks are averaged to establish the strength value of the plant.

The rate of travel of the rolling weight was adjusted so that at least 3 seconds elapsed between the time of release of the weight and the time the weight reached the maximum limit of travel. This rate was found to be the minimum which could be used in order to provide free rolling of the weight and a minimum of overshoot.

Fiber strength determinations were made for individual plants of the recurrent selection population, the F_4 population and the parent progenies by the procedure previously outlined. Samples of a check cotton were tested at the beginning and at the end of each four-hour work period to provide a basis for converting results to standard conditions for evaluation. The check used was a selection of Acala, having a known strength index of approximately 2.99. A conversion factor was calculated by the use of the formula: $\text{Conversion Factor} = \frac{\text{Average strength index of check}}{\text{Known strength index of check}} \times 100.$ The average strength index for each plant was multiplied by this factor to establish the plant strength value.

The fiber strength determinations were made in a laboratory having controlled conditions, a standard temperature of 70° F. and relative humidity of 65%.

After the strength determinations for all of the lint samples had been made, 102 samples were measured a second time in order to check the reliability of the original strength measurements. An attempt was made to choose 1 plant at random from each of the F_4 progenies and the intercross progenies. The strength determinations were made in the same manner as the original determinations without knowledge of the original strength index values of the plants being retested.

RESULTS AND DISCUSSION

The results reported in this dissertation are a part of a cotton breeding project at the Louisiana Agricultural Experiment Station. One objective of this program is to increase the fiber strength of American Upland cotton through interspecific hybridization by utilizing the high strength of Sea Island cotton.

The phase of the study reported herein is an attempt to increase the fiber strength of Upland cotton by the use of recurrent selection. The use of this breeding method with cotton has not been reported in which lines resulting from an interspecific cross between Sea Island and Deltapine 15 were used. The latter is one of the most important cotton varieties of Louisiana. Recurrent selection has been used to improve inbred lines of corn for a number of years. More recently it has been utilized in the improvement of various species of forage legumes and grasses.

Eight F_3 lines derived from a cross between Deltapine 15 and Sea Island cotton were intercrossed in all possible combinations. Lint strength determinations of the intercross populations are reported herein.

Reliability of Strength Determinations

In making fiber strength determinations with the Pressley strength tester the operator should have skill in operating technique in order to assure relatively accurate strength index values. In this study the writer retested 102 randomly selected plants after the original tests had been completed in an effort to study the reliability of the strength determinations. Plants from all of the F_4 and the intercross populations were represented in the retests.

The differences between the first and the second determinations ranged from 0.58 strength index unit above the first determination to 0.47 unit below the first determination. The first and the second determinations were identical for 2 of the 102 plants which were retested for strength.

In 63 of the 102 plants which were retested, the difference between the 2 determinations did not exceed 0.15 strength unit. The results for these 63 plants may be considered to be highly reliable, since the agreement between the 2 strength index values of an individual plant was close. These 63 plants represent 62% of the plants retested.

In 28 of the 102 plants, the difference between the 2 determinations ranged from 0.16 through 0.30 strength unit. This represents 28% of the retested plants. The results from these plants were less reliable than those for the previous group, but they would not appear to be sufficiently unreliable to have a serious effect on the conclusions drawn. Seven of these 28 plants had a higher strength index value in the second determination than in the first, while 21 plants had lower strength index values in the second determination than in the first determination.

In a third group, consisting of 11 plants, the 2 determinations differed by more than 0.30 strength index unit. This constitutes about 10% of the 102 plants retested. The results from these plants appear to be unreliable. Of these 11 plants, 4 of the second determinations were higher than the first, while for the other 7 plants the second determination was lower than the first.

These differences of over 0.30 strength index unit between determinations suggest a tendency for the operator to estimate fiber strength too high or too low occasionally. For the 11 plants in which the difference between the 2 determinations exceeded 0.30 unit, there was a tendency for the retests to be higher in 36% of the plants and lower in 64% of the plants. Whether the errors occurred in the first or the second determinations was not determined. It would appear that because of this occasional tendency to get a strength index value higher or lower than it should be, about 10% of the determinations are in error by 0.30 unit or more.

Various possible causes for this sizable error tendency were considered. The strength index values were rechecked for accuracy in recording. The differences could have been caused by inexperience of the operator at the beginning of the testing period or by some change in the laboratory equipment or conditions. Any of these causes would have been indicated by a grouping of these major differences among the determinations which were made while the equipment or conditions were defective. These various possibilities were examined, and no evidence that they were the cause of the major differences was found. Therefore, it was concluded that they did not account for the differences between the first and the second strength determinations of the plants.

Thirty-nine of the 102 plants that were retested had differences between the first and second strength index determinations which exceeded 0.15 strength index unit. Twenty-eight of these 39 differences resulted from retest strength index values being lower than the original strength index values. This seems to be higher than could be accounted for by chance and appears to indicate a tendency for the second determinations, which were made at the end of the study, to be much lower in some plants than the original measurements made earlier in the study. This suggests that most of the large differences could have been caused by a change in the operator's technique. Had the differences been due to chance, they would have been about equally divided between lower and higher determinations for the retest values.

The correlation coefficient for the first and the second determinations ($r = 0.901$) was highly significant. Although high, this r value is somewhat misleading. Although it indicates a close association between 2 sets of strength index values, it does not indicate the wide differences between the 2 strength index values for some of the plants.

Based on these retest results, 38% of the original strength determinations could be subject to question. However, probably not more than

10% were in great enough error to be of serious nature. Practically speaking, approximately 90% of the differences were so small as to be unimportant.

The strength determinations of any individual plant in about 10% of the strength determinations is probably unreliable. However, when the strength index values are considered as averages of populations consisting of many plants it may be concluded that the results reported for fiber strength in this study are reliable.

Strength of the F_3 Lines Used as Parents in Intercrosses

The fiber strength means for the parents and the 8 selected F_3 lines which were used in the intercrosses on which this study is based are given in table 2. The strength index values for the parents are given for 1956 only. The strength index values of the parents for 1957 were not available. The strength index values for the 8 F_3 lines for 1956 and 1957 and a 2-year strength index mean of each of the 8 F_3 lines are given.

In 1956 fiber strength determinations were made for each of the 8 F_3 lines. The strength index value for each line in table 2 represents the mean strength index from two 20-boll samples picked at random from among the plants within that particular line. These 8 lines were not the 8 highest strength lines of the 51 F_3 lines which were progeny tested in 1956. They were selected from 51 F_3 lines on the basis of 3 other characters in addition to fiber strength. Consequently, some of the 8 F_3

Table 2. Strength index values of the original parents and eight F_3 lines used as parents in recurrent selection, when grown in two different years.

Parents and F_3 line numbers	Strength index 1956	1957	Mean
Deltapine 15	3.33	-	-
Sea Island	5.36	-	-
13	4.15	3.51	3.83
14	4.79	3.54	4.17
15	4.65	4.12	4.39
16	3.99	3.70	3.85
17	4.39	3.90	4.15
18	4.74	4.45	4.60
19	4.53	4.26	4.40
20	4.08	3.60	3.84

Data supplied by Warren A. Meadows, Louisiana State University, Baton Rouge, Louisiana.

lines had fiber strength indices below the average strength index of the parents.

The strength index mean of the Deltapine 15 parent was 3.33 units, while the mean of the Sea Island parent was 5.36. There was a considerable difference between the 2 parents of the cross as shown by the mean difference of 2.03 strength index units. The arithmetic average of the parents was 4.35 units.

The 1956 mean strength indices of the 8 F_3 lines ranged from 3.99 units for line 16 to 4.79 units for line 14, a difference of 0.80 unit.

Three of the 8 F_3 lines had a mean strength value which was below the average of the parents. These were line 16, which had a mean of 3.99 units; line 20, which had a mean of 4.08; and line 13 which had a mean of 4.15.

Line 17 had a strength index mean of 4.39 units, which was essentially equal to the arithmetic mean of the parents.

Four of the 8 F_3 lines had strength index values well above the arithmetic mean of the parents. These were line 19 with a mean of 4.53 strength index units, line 15 with a mean of 4.65, line 18 with a mean of 4.74 and line 14 with a mean of 4.79 units. However, the mean of the line having the highest strength (line 14) was still 0.57 unit below the mean of the stronger parent.

For 1957, the strength index values for the 8 F_3 lines used in intercrosses are given. The reported strength index values are the means of the values for the plants from which intercrosses were attempted in a particular F_3 line. For example, the strength index given for F_3 line 13 is the mean of the fiber strength determinations for plants 13-1, 13-2, 13-3, 13-5 and 13-6. The number of plants represented in the mean of a single F_3 line, or the number of plants of that line used in intercrosses, varied from 5 in line 13 to 7 in lines 18 and 20.

The 1957 strength index values for the 8 F_3 lines ranged from 3.51 units for line 13 to 4.45 units for line 18, a difference of 0.94 unit. This is a comparatively large difference for a group of lines selected for high strength.

Based on probable performance of the parents, 4 of the 8 lines had relatively low strength indices. These were line 13 with a strength index value of 3.51, line 14 with an index value of 3.54, line 20 with an index value of 3.60 and line 16 with a mean of 3.70 units.

One of the 8 F_3 lines had an intermediate strength index value. This was line 17 with an index value of 3.90 units.

Three of the 8 F_3 lines had strength values which were relatively high. These were line 15 with a strength index of 4.12, line 19 with a value of 4.26 and line 18 with a value of 4.45.

The means of the 1956 and the 1957 strength index values of the 8 F_3 lines ranged from 3.83 to 4.60 units, a difference of 0.77 unit. The 2-year means indicate that 3 of the 8 F_3 lines were relatively low in fiber strength. These were lines 13, 16 and 20. Two of the 8 F_3 lines had a 2-year mean strength which was intermediate. These were lines 14 and 17. The remaining 3 of the 8 F_3 lines had moderately high 2-year means for fiber strength index. These were lines 15, 18 and 19.

The agreement of the relative fiber strength determinations for the 2 years was good in 7 of the 8 F_3 lines tested. The strength indices of lines 13, 16 and 20 were low for both years. Line 17 was intermediate for both years. Lines 15, 18 and 19 were moderately high in both years.

This amount of agreement between fiber strength determinations in the 2 years indicates that the method of sampling used in the 1957 study was reasonably effective. Since for each line studied in 1956 a large number of plants were sampled, it is assumed that the 1956 results are highly reliable, or a highly reliable indication of the relative strength of the 8 F_3 lines. However, the 1957 results for each line are based on only 4 to 7 plants tested. It would appear from the results in this study that the 4 to 7 plants chosen at random from each F_3 line appear to provide a reasonably adequate sample of that line. This suggests that the use of 4 to 7 plants per line for intercrossing in recurrent selection would be a reasonably satisfactory procedure.

Line 14 was the only one of the 8 F_3 lines which had poor agreement between its 1956 and 1957 strength indices. This line was included in the high strength class as an F_3 line in 1956, while it was in the low strength class in 1957. As handled in this study, line 14 was presumably satisfactory, but the method of sampling for intercrosses in recurrent selection was unsatisfactory.

The sampling procedure used in 1956 would seem to be reliable. This would appear to indicate that the 1956 results were probably reliable and that line 14 had a moderately high strength. Consequently, the 1957 results would appear to require explanation. For each F_3 line the seed planted in both years was obtained from the same F_2 plant. Four plants were taken at random from F_3 line 14 and the 1957 results represent the average of these 4 plants. The 4 plants had strength indices below the probable average of the 2 parents. Presumably, line 14 was highly heterozygous for fiber strength and would therefore contain plants which differed widely in fiber strength. Some of these had low strength, although the majority were high enough to give a high mean. It was assumed further that by chance all of the 4 plants chosen at random for intercrossing were low in strength.

The basic assumption in recurrent selection is that the performance of lines as such is correlated with their performance in intercrosses. For example, low fiber strength lines would produce low strength intercrosses, average strength lines would produce intermediate intercrosses and high strength lines would produce high strength intercrosses.

Based on their relative strength classes in 1956 and 1957, lines 13, 16 and 20, which were low strength lines, might be expected to produce low strength intercrosses. Line 17 was intermediate in strength as a line. Therefore, intercrosses which involve line 17 should be average in performance. Three of the lines (15, 18 and 19) were moderately high in their performance as lines. These moderately high lines should produce intercrosses moderately high in fiber strength. Line 18 appears to be the most outstanding of the 8 F_3 lines with respect to line performance. The performance of line 18 in intercrosses might be expected to be superior to the other 7 lines.

Although the strength of line 14 apparently was high as a line, the 4 plants selected from it for use in intercrosses had low strength. Therefore, the intercrosses derived from line 14 in this study might be expected to be low in performance.

Behavior of F_4 Progenies Derived from F_3 Plants Used in Intercrosses

The mean strength index of each of the F_4 progenies which were derived from F_3 plants used in intercrosses is given in table 3. These F_4 progenies were grown in 1958 with the parents and intercross populations. Each F_4 progeny was designated by the same number as the F_3 plant from which it was derived, as 13-1. An F_4 population which consisted of all the F_4 progenies which were derived from 1 F_3 line, was designated by the same number that was assigned to the F_3 line from which it was derived.

F_4 population 13 consisted of 3 F_4 progenies having a total of 39 plants. The mean strength indices of the F_4 progenies ranged from 2.99 to 3.43 units, with a difference of 0.44 unit. This population had a moderate amount of variability.

The mean strength index of the 3 F_4 progenies of F_4 population 13 was 3.24 units. One of the F_4 progenies (13-3) had a mean of 2.99

Table 3. Mean strength of F_4 progenies grown in 1958 and derived from the F_3 plants which were used in recurrent selection.

Parent and F_4 population	Mean strength of F_4 progeny derived from the following F_3 plants									
	1	2	3	4	5	6	7	8	No.	Mean
Deltapine 15									57	2.70
Sea Island									67	4.07
13	3.31	-	2.99	-	3.43	-	-	-	39	3.24
14	3.46**	3.34	-	3.35	3.47	-	-	-	40	3.40
15	3.53	3.63	3.30	3.64	3.91	3.48	-	-	94	3.58
16	-	-	3.09**	-	3.14	3.40	3.63**	3.14	37	3.30
17	3.20	-	-	-	3.54	3.84	-	3.26	66	3.46
18	3.40	-	4.69	-	4.10**	-	3.64**	-	27	3.95
19	3.23	3.66	3.52	4.07	3.48	-	3.37	-	92	3.55
20	-	3.37	3.90*	3.52	3.29	3.71	2.89*	3.64	71	3.47

*Only 1 plant tested in these progenies

**Only 2–4 plants tested in these progenies units, which was only slightly above the mean of the weaker parent. The strength of population 13 as a whole was relatively low. The strength of F_3 line 13, from which F_4 population 13 was derived, was also low. Thus, there was agreement between the performance of F_3 line 13 and that of the progenies derived from it.

F_4 population 14 consisted of 4 F_4 progenies having a total of 40 plants. The mean strength indices of these progenies ranged from 3.34 to 3.47 units, with a range of only 0.13 unit. Thus, the F_4 progenies of population 14 showed essentially no detectable genetic variation.

This suggests that F_3 line 14 was relatively homozygous. However, it has been concluded earlier from 1956 and 1957 results from line 14 that it was heterozygous for fiber strength. It appears probable then that 4 plants of approximately the same fiber strength were taken at random from this heterozygous line. The mean of F_4 population 14 was 3.40 units, which was the same as the mean of the parents, consequently the results of the F_4 progeny test indicate that the plants chosen from line 14 for intercrosses were average in performance. This conclusion agrees in a general way with that drawn from the 1956-1957 data for line 14, from which it was concluded that the plants chosen from line 14 for intercrosses were relatively low in strength.

F_4 population 15 consisted of 5 F_4 progenies containing a total of 94 plants. The mean strength index of the F_4 progenies ranged from 3.30 to 3.91 units, a difference of 0.61 unit. Thus, there was a considerable amount of variation among the progenies of F_4 population 15. The mean strength index of population 15 was 3.58 units. The mean of one of the progenies (15-5) approached the mean of the stronger parent, being only 0.16 unit lower than the mean of Sea Island. The relative mean strength of population 15 was moderately high. Thus, the strength performance of the F_4 population 15 was in agreement with the performance of the F_3 line 15 from which it was derived, which was placed in the relatively high class.

However due to the high degree of genetic variation among the 5 plants of line 15 that were used in intercrosses, the performance of individual intercross progenies involving line 15 cannot be predicted reliably from the mean performance of F_4 population 15. One of the F_3 plants chosen for intercrosses (15-3) produced a progeny of an average strength, while progeny of 15-5 was exceptionally high. It can be assumed that these 2 plants of line 15 would perform differently in intercrosses.

F_4 population 16 consisted of 5 F_4 progenies containing a total of 37 plants. The mean strength indices of the F_4 progenies ranged from 3.09 to 3.63 units, a difference of 0.54 unit. There was a moderate amount of variation among the progenies of population 16. The mean strength index of population 16 was 3.30 units. Three of the 5 progenies were well below the mean of the parents and only 1 progeny was appreciably higher than the parent mean. The mean of population 16 was relatively low. Thus, the strength performance of F_4 population 16 was in agreement with the performance of F_3 line 16 from which it was derived (table 2). However, F_3 plant 16-7 might be expected to give a moderately high performance in intercrosses.

F_4 population 17 consisted of 4 F_4 progenies containing a total of 66 plants. The mean strength indices of the 4 F_4 progenies ranged from 3.20 to 3.84 units, a difference of 0.64 unit. There was a considerable amount of variation among the progenies of F_3 line 17. The mean strength index of F_4 population 17 was 3.46, about equal to the average of the parents. Thus, the strength of F_4 population 17 was intermediate and the strength performance of this population agreed with the performance of F_3 line 17, from which it was derived. However, 2 plants (17-1 and 17-8) were low and 1 plant (17-6) was high. These 3 plants probably would not give intermediate performance. Only 1 plant of the 4 would give intermediate performance. Thus, it might not be possible to predict reliably the performance of F_3 line 17 from the performance of the 4 F_4 progenies.

F_4 population 18 consisted of 4 F_4 progenies having a total of 27 plants. The mean strength indices of these 4 progenies ranged from 3.40 to 4.69 units, a difference of 1.29 units. This difference of 1.29 units was almost as high as the mean difference between the parents (1.37 units), indicating a high variation in F_4 population 18. The mean strength index of F_4 population 18 was 3.95 units, on the basis of which the relative strength of this population would be classed as high. This agrees in a general way with the conclusion based on the performance of F_3 line 18 in 1956 and 1957, from which it was concluded that the strength performance of that line was moderately high.

The high strength index mean of F_4 population 18 was based on 4 F_4 progeny means, 1 of which was abnormally high, 1 high, 1 moderately high and 1 average in fiber strength. F_4 progeny 18-5, although having a mean like the Sea Island parent, had some individual plants above the Sea Island strength range, indicating a different type of behavior. The strength index mean of F_4 progeny 18-3 (4.69 units) indicated abnormally high strength behavior.

F_4 progeny 18-3 was made up of 5 plants. The strength of 4 of these plants was higher than that of any plant of the high strength Sea Island parent. The strength index of these 4 abnormally high strength plants ranged from 4.57 to 5.14. No explanation was apparent for occurrance of abnormally high strength plants in F_4 progeny 18-3. However, the condition does appear to be associated with the fact that the material was developed from interspecific hybridization. Worley (41) found a few F_3 plants with fiber strength higher than that of any plants of the Sea Island parent. Since the cause of the abnormally high strength is unknown, it is not possible to predict the behavior of F_3 line 18 in intercrosses.

F_4 population 19 consisted of 6 F_4 progenies having a total of 92 plants. The mean strength indices of these 6 progenies ranged from 3.23 to 4.07 units, a difference of 0.84 unit. This difference is an indication that a considerable amount of variation existed in population 19. The strength of F_4 population 19 was moderately high. Thus, the performance of F_4 population 19 agreed with the performance of F_3 line 19 from which it was derived.

Because of the wide variation in the mean strength of the F_4 progenies of F_3 line 19, there might be some question about classifying it as moderately high. F_4 progeny 19-4 had a high strength index mean of 4.07 units, which was the same as the Sea Island mean. However, this progeny was not similar to Sea Island in behavior, since it contained several plants having fiber strength above the range of the Sea Island parent, a condition reported previously for F_4 progeny 18-3. The strength behavior of some of the plants of F_3 line 19 in intercrosses might be moderately high, while that of 19-4 would be uncertain.

F_4 population 20 consisted of 7 F_4 progenies having a total of 71 plants. The mean strength indices of these progenies ranged from 2.89 to 3.90 units, a difference of 1.01 units. This difference indicates that the F_4 progenies of F_4 population were highly variable. The mean strength index of F_4 population 20 was 3.47 units. The strength performance of F_4 population 20 was intermediate, when based on the population mean.

It would not be possible to predict the performance of F_3 line 20 from the highly variable performance of F_4 population 20. Some of the F_4 progenies derived from individual plants of F_3 line 20 were low in strength, others were average, moderately high or high. Consequently, the performance of F_3 line 20 in intercrosses will vary greatly with the performance of the individual plants of this line which were involved.

Based on the performance of the 8 F_3 lines and on the performance of F_4 progenies of these F_3 lines, strength classification was consistent for 5 of the 8 lines. These 5 lines were 13 and 16, which were classed as low strength in F_3 and in F_4; line 17, which was classed as intermediate; and lines 15 and 19, which were classed as moderately high. The strength classification for F_3 and F_4 agreed in a general way for the remaining 3 F_3 lines. Lines 14 and 20 were classed as low in F_3 and as intermediate in F_4, while line 18 was classed as moderately high in F_3 and as high strength in F_4.

Behavior of Intercrosses Among the Eight F_3 Lines

A frequency distribution and statistical values for the parental strains and 1023 plants representing 20 intercross populations among the 8 F_3 lines and consisting of a total of 84 intercross progenies are given in table 4. Intercross populations are designated by the numbers assigned to the F_3 lines involved in the crosses from which they were derived, as 13 x 15. Intercross progenies are designated by the F_3 line and numbers of the plants from the 2 F_3 lines involved in the intercross, as previously explained. The plants in each intercross progeny are grouped into class intervals of 0.2 strength index unit, and each class is designated by its mean.

As indicated in table 4, the fiber strength index values of the plants of the Deltapine 15 parental strain ranged from 2.5 to 3.1 class

Table 4. Frequency distribution of parents and twenty intercrosses involving eight F_3 lines.

Population	No. plants in strength index classes													$\bar{x}$	N
	2.5	2.7	2.9	3.1	3.3	3.5	3.7	3.9	4.1	4.3	4.5	4.7	4.9		
Parents															
Deltapine 15	19	22	15	1										2.70	57
Sea Island						1	11	18	16	12	9			4.07	67
													Mean	3.39	
Intercrosses															
13 x 15															
13-1 x 15-3			1	3	2	1	1							3.27	8
13-3 x 15-2			1	2		3	1	1						3.38	8
13-3 x 15-5			2	3	1	3	2							3.30	11
13-5 x 15-2			2	1	3	1	1	1						3.24	9
													Mean	3.30	
13 x 18															
13-1 x 18-1					1	1	3	4			1			3.84	10
13-3 x 18-1				2	2	3		1						3.38	8
13-5 x 18-7					5		2							3.40	7
													Mean	3.54	
13 x 19															
13-1 x 19-1				3	2	3	5		3					3.58	16
13 x 20															
13-1 x 20-3				2	3	3	2	1	1					3.25	12
13-5 x 20-4				2	5	3	1		1					3.41	12
13-5 x 20-7				1	2	2	2	2	1	1				3.60	11
													Mean	3.42	

Table 4. (Continued)

Population	No. plants in strength index classes 2.5	2.7	2.9	3.1	3.3	3.5	3.7	3.9	4.1	4.3	4.5	4.7	4.9	x̄	N
							14 x 15								
14-2 x 15-2			1	2	2	1	1							3.23	7
14-2 x 15-4	1		2	6	2	2	2							3.19	15
14-2 x 15-5					1	6	4	5	1	2				3.75	19
14-4 x 15-5					1	3	3		3			1		3.82	11
14-4 x 15-6				1	1	2	3			1				3.61	8
14-5 x 15-2			1	1	2	2	2	2	1	1		1		3.68	13
													Mean	3.55	
							14 x 18								
14-1 x 18-1			4	1	4	2								3.17	11
14-2 x 18-1		2	4	6	3	3	1							3.17	19
14-4 x 18-1				1	2	1	2	1						3.49	7
14-5 x 18-1						3	2	2	2	2				3.89	11
14-5 x 18-7					1	1	4	2	1	2				3.83	11
													Mean	3.51	
							14 x 19								
14-1 x 19-1			2	2	4	3	1	1	2	1	1			3.56	17
14-1 x 19-2				1	8	3	4	1	1					3.52	18
14-1 x 19-3		1	4	4	7	3	1	1	1					3.29	22
14-1 x 19-4	1	2	1		4									2.98	8
14-4 x 19-1				1	2	3	6		1	2			1	3.77	16
													Mean	3.42	
							15 x 16								
15-2 x 16-7						1	2	2	1					3.85	6
15-3 x 16-5			3	3	3	5	2	1						3.35	17
15-6 x 16-5						1	2	3	4	2	1			4.02	13
													Mean	3.74	

Table 4. (Continued)

Population	No. plants in strength index classes													$\bar{x}$	N
	2.5	2.7	2.9	3.1	3.3	3.5	3.7	3.9	4.1	4.3	4.5	4.7	4.9		
							15 x 17								
15-3 x 17-5		1		2		2	2	1						3.43	8
15-5 x 17-6							2		2	1	1			4.08	6
													Mean	3.76	
							15 x 18								
15-1 x 18-1				3	4	4	3	3	1					3.58	18
15-3 x 18-1			1		3	2		2						3.47	8
15-4 x 18-3						1		1	7	1	2	1		4.14	13
15-6 x 18-5								1	1	1				4.14	3
													Mean	3.48	
							15 x 19								
15-1 x 19-1						2	2	1	2					3.82	7
15-2 x 19-1						1	1	3						3.83	5
15-2 x 19-3				1	3	6	2	3	1	1				3.60	17
15-3 x 19-3				4	2	7	1	2	2					3.53	18
15-3 x 19-5			1	5	8	6	1		1					3.37	22
15-5 x 19-3				2	1				1					3.42	4
15-6 x 19-7				1		2	1	1	3					3.76	8
													Mean	3.62	
							15 x 20								
15-2 x 20-4	1	1	1		1		2	2						3.37	8
15-3 x 20-8					1		2							3.52	3
15-4 x 20-5				1	5	2	7	3						3.58	18
													Mean	3.49	

Table 4. (Continued)

Population	No. plants in strength index classes													$\bar{x}$	N
	2.5	2.7	2.9	3.1	3.3	3.5	3.7	3.9	4.1	4.3	4.5	4.7	4.9		
							16 x 17								
16-3 x 17-8			1	3	6	4	3	1						3.40	18
							16 x 19								
16-5 x 19-1					2	4	1	1	1					3.56	9
16-6 x 19-1				2	1	6	5	1						3.54	15
16-7 x 19-5					2	1	4	1		2				3.74	10
16-8 x 19-3			1	2	5	2		1						3.34	11
													Mean	3.52	
							17 x 18								
17-6 x 18-7						5	1	1		1				3.67	8
17-8 x 18-5				1	2	3	3	2	1		1			3.69	13
17-8 x 18-7				1	2	6	1	1	1					3.46	12
													Mean	3.61	
							17 x 19								
17-1 x 19-3				1	6	1		1						3.38	9
17-5 x 19-1					1	3	1	2	2	1		2		3.94	12
17-5 x 19-2				2	5	2		2						3.46	11
17-5 x 19-3			1	1		1	2	6	1	2				3.80	14
17-6 x 19-5			1		1	4	3	3			2			3.71	14
17-6 x 19-7				3	4	5	1	4	2	2				3.62	21
17-8 x 19-5			1		4	3	5	2						3.50	15
													Mean	3.63	
							17 x 20								
17-1 x 20-8						1	2							3.68	3
17-5 x 20-8		1			4	4	3	5		2	1			3.73	20
17-8 x 20-8					3	6	7							3.56	16
													Mean	3.66	

Table 4. (Continued)

Population	No. plants in strength index classes													$\bar{x}$	N
	2.5	2.7	2.9	3.1	3.3	3.5	3.7	3.9	4.1	4.3	4.5	4.7	4.9		
							18 x 19								
18-1 x 19-1						1	1	1	6	2		2	1	4.20	14
18-1 x 19-3							2	1	1	2	1	1		4.14	8
18-1 x 19-5							1							3.70	1
18-5 x 19-1				1	1	1	1	6	4	3	1			3.93	18
18-5 x 19-5								1						3.87	1
18-7 x 19-2					1	3	5	2	1					3.70	12
18-7 x 19-3				1		1	2	2						3.65	6
18-7 x 19-4				2	1	2	1	3	2	1				3.76	12
													Mean	3.87	
							18 x 20								
18-1 x 20-3			2	1	1	2	2	1	2	1				3.65	12
18-1 x 20-7			2		3	5	2	2	1		1			3.55	16
18-3 x 20-7						1	2	1	6	1				3.98	11
18-5 x 20-4				3	1	3	2	2	1					3.55	12
18-7 x 20-7				1	1	1	1	3	3	4				3.93	14
18-8 x 20-8		1	3	2	6	8	2	2						3.35	24
													Mean	3.67	
							19 x 20								
19-1 x 20-2			1	3	7	7	1	1						3.39	20
19-1 x 20-8						1	2	2	4	1	1			4.00	11
19-2 x 20-7			6	1	4	1		1						3.18	13
19-3 x 20-7		1	2	6	7	5	1	1						3.29	23
19-4 x 20-7						4	3	2	4	3	1			3.95	17
19-4 x 20-8				1	1	2	2	6		3	3	2		3.99	20
													Mean	3.63	

intervals with a mean of 2.70 units. The strength index values of the plants of the Sea Island parental strain ranged from 3.5 to 4.5 class intervals with a mean of 4.07 units. Thus, there was a considerable difference between the 2 parents as shown by the mean difference of 1.37 strength index units. The arithmetic average of the parental means was 3.39 strength index units.

Intercross Population 13 x 15

Four progenies of intercross population 13 x 15, containing from 8 to 11 plants each, were studied (table 4). These 4 progenies involved plants 1, 3 and 5 of F_3 line 13 and plants 2, 3 and 5 of F_3 line 15. In terms of strength class intervals, the strength variation in the 4 progenies was similar. Intercross progenies 13-1 x 15-3 and 13-3 x 15-5 had a range from 2.9 to 3.7, or 5 strength classes; while 13-3 x 15-2 and 13-5 x 15-2 had a range from 2.9 to 3.9 or 6 strength class intervals. The strength index means of the four 13 x 15 intercross progenies ranged from 3.24 to 3.38 units, a difference of only 0.14 unit.

The 13 x 15 intercross population had a strength range from 2.9 to 3.9, or 6 class intervals. Thus, there was not an appreciable amount of variation among intercross progenies of population 13 x 15. All 4 progenies were very similar in distribution of plants and means. Furthermore, there was little evidence of genetic variation within each of the intercross progenies.

As indicated in table 3 and the earlier discussion of that table, all plants of the F_3 lines which were used as parents in intercrosses were progeny tested individually as F_4 lines in the same experiment with the intercrosses themselves. Thus, selfed progenies of plants 13-1, 13-3, 13-5, 15-2, 15-3 and 15-5 were grown separately in 1958 and evaluated for fiber strength (table 3). Based on the performance of these F_4 lines, the F_3 plants used in intercrosses had been classified as low, average, moderately high and abnormally high in fiber strength. Also on the basis of these results each line had been placed in similar strength classes. The F_4 progenies of plant 13-3 had low strength while the F_4 progenies of plants 13-1 and 13-5 were intermediate. The F_4 progenies of 15-3, 15-2 and 15-5 differed greatly in fiber strength. That of 15-3 was intermediate, 15-2 was moderately high and 15-5 was high in strength.

A greater variation in intercross progenies might have been expected as a result of crossing these F_3 plants than that shown in table 4, especially in intercrosses involving plants 15-2 and 15-5. However, there was a similarity in the strength index range and mean for all of the 13 x 15 intercross progenies.

No 13 x 15 intercross progeny appears to be valuable for recurrent selection, and the 13 x 15 intercross population as a whole appears to be inferior.

Intercross Population 13 x 18

Three progenies of intercross population 13 x 18, containing from

7 to 10 plants per progeny, were studied (table 4). These 3 progenies involved plants 1, 3, and 5 of F_3 line 13 and plants 1 and 7 of F_3 line 18. The strength range of the 3 progenies included from 3 to 7 strength index class intervals per progeny. Progeny 13-1 x 18-1 showed a relatively wide degree of variation, while the other 2 progenies had a low degree of variation. The strength index means of the three 13 x 18 intercross progenies ranged from 3.38 to 3.84 units, a difference of 0.46. The mean of intercross progeny 13-3 x 18-1 was 3.38 strength index units, and that of 13-5 x 18-7 was 3.40 units. These 2 progenies were intermediate in strength. The mean of intercross progeny 13-1 x 18-1 was 3.84 units, or high in strength.

The 13 x 18 intercross population had a strength range from 3.1 to 4.5, or 8 class intervals. The strength index mean for the population was 3.54 units.

Of the F_3 plants involved in intercross 13 x 18, plant 3 of F_3 line 13 was classed as low strength, while 1 and 5 of line 13 were intermediate. Plant 1 of line 18 was intermediate, while plant 7 of line 18 was moderately high in strength (table 3). The low strength behavior of 13-3 x 18-1 was approximately as expected since 1 parent plant was classed as low and the other intermediate in strength. Progeny 13-5 x 18-7 did not behave as expected. The 13-5 parent was classed as intermediate and 18-7 as moderately high in strength. The mean of the progeny was below that of the low parent. In 13-1 x 18-1 the combination of 2 intermediate parent plants might have been expected to produce an intermediate intercross progeny. However, this cross resulted in a high strength progeny. It is difficult to account for this unexpected result.

One of the 13 x 18 intercross progenies appeared to have value in recurrent selection. This progeny was 13-1 x 18-1, which had a high strength mean and a high frequency of high strength plants, some of which approached the mean of the stronger parent. The other 2 progenies appeared to be mediocre in value.

Intercross Population 13 x 19

Only one intercross progeny of intercross 13 x 19 was studied (table 4). This progeny contained 16 plants and involved plant 1 of F_3 line 13 and plant 1 of line 19. The strength of the progeny ranged from 3.1 to 4.1, or 6 strength class intervals. The mean of the progeny was 3.58.

A low and an average strength parent plant were involved in intercross progeny 13-1 x 19-1 (table 3). These low and average strength parent plants might have been expected to produce a progeny which was inferior in strength. Progeny 13-1 x 19-1, however, was moderately high in strength.

Progeny 13-1 x 19-1 contained a number of plants with strength approaching that of the Sea Island parent. It should be of moderate value in recurrent selection.

<u>Intercross Population 13 x 20</u>

Three intercross progenies of intercross population 13 x 20, containing 11 to 12 plants per progeny, were studied (table 4). These 3 progenies involved plants 1 and 5 of F_3 line 13 and plant 3, 4 and 7 of F_3 line 20. The strength range of the 3 progenies included from 6 to 7 strength index class intervals per progeny. Thus, the strength ranges of the 3 progenies were similar. Intercross progenies 13-1 x 20-3 and 13-5 x 20-4 ranged in strength classes from 3.1 to 4.1, or 6 class intervals. Intercross progeny 13-5 x 20-7 ranged from 3.1 to 4.3, or 7 class intervals. Thus, the strength index ranges of the 3 progenies of intercross population 13 x 20 were similar. The strength index means of the three 13 x 20 intercross progenies ranged from 3.25 to 3.60, a difference of 0.35 unit. Of the 3 intercross progenies of the 13 x 20 intercross population, 13-1 x 20-3 had a mean of 3.25 units, or low strength. Progeny 13-5 x 20-4 had a mean of 3.41 units, or intermediate strength. Progeny 13-5 x 20-7 had a mean of 3.60 units, or moderately high strength.

The 13 x 20 intercross population had a strength range from 3.1 to 4.3, or 7 strength class intervals. The strength index mean for the population was 3.42 units.

Of the F_3 plants involved in intercross 13 x 20, plants 1 and 5 of line 13 were intermediate in F_4 progeny mean strength. Plant 7 of line 20 was very low, plant 4 of line 20 was moderately high and plant 3 of line 20 was high in strength.

Based on the F_4 progeny performance of the F_3 lines from which they were derived, intercross progenies 13-1 x 20-3 and 13-5 x 20-4 had mean strength performance considerably lower than would have been expected. In intercross progeny 13-5 x 20-7, the combination of an average strength plant with an extremely low strength plant would have indicated a progeny below average. However, the strength performance of this progeny was moderately high. However, the unusually low F_4 progeny mean of plant 7 of line 20 represented a 1-plant progeny which could have been unreliable.

As a population 13 x 20 was only mediocre in performance. However, intercross progeny 13-5 x 20-7 should be moderately satisfactory for recurrent selection because of its frequency of high strength plants which approach the mean of the Sea Island parent.

Intercross Population 14 x 15

Six progenies of intercross population 14 x 15, containing from 7 to 19 plants per progeny, were studied (table 4). These 6 progenies involved plants 2, 4 and 5 of F_3 line 14 and plants 2, 4, 5 and 6 of F_3 line 15. The degree of strength variation within progenies varied widely for the 6 studied. Intercross progeny 14-2 x 15-2 ranged only from 2.9 to 3.7, or 5 class intervals. Intercross progeny 14-2 x 15-4 ranged from 2.5 to 3.7, or 7 class intervals. Progeny 14-2 x 15-5 ranged from 3.3 to 4.3, or 6 class intervals. Progeny 14-4 x 15-5 ranged from 3.3 to 4.7, or 8 class intervals. Progeny 14-4 x 15-6 ranged from 3.1 to 4.3, or

7 class intervals. Progeny 14-5 x 15-2 ranged from 2.9 to 4.7, or 10 strength class intervals. Thus, part of the progenies showed relatively low variation, while others, such as 14-5 x 20-2 showed a wide degree of strength variation. This wide variation within certain of the progenies indicates that a great amount of genetic variation exists within those progenies.

The strength index means of the six 14 x 15 intercross progenies ranged from 3.19 to 3.82 units, or a difference of 0.63 unit. The mean of intercross progeny 14-2 x 15-2 was 3.23 and that of 14-2 x 14-4 was 3.19. Thus, both of these progenies were low in strength. Progeny 14-4 x 15-6 had a mean of 3.61 units and would be classed as moderately high in strength. The remaining 3 of the 6 intercrosses had mean strength of 3.68 and above and would be classed as moderately high to high in strength.

The 14 x 15 intercross population had a strength range from 2.5 to 4.7, or 12 class intervals. The strength index mean for the population was 3.55 units, or moderately high.

Progeny 14-2 x 15-5 is especially noteworthy. This progeny had a low degree of variation combined with a high mean of 3.75. Both in distribution of plants and mean, this progeny did not differ greatly from the Sea Island parent.

Of the F_3 plants involved in intercross 14 x 15, plants 2, 4 and 5 of F_3 line 14 were average in strength. Plant 6 of line 15 was also average, plants 2 and 4 of line 15 were moderately high, and plant 5 of line 15 was high in strength (table 3).

Line 14 was classified as intermediate in strength and line 15 as moderately high.

Two of the progenies of population 14 x 15, 14-2 x 15-2 and 14-2 x 15-4, were distinctly inferior in respect to fiber strength. In both of these progenies one of the parents was classified as intermediate and the other as moderately high. Consequently, the poor performance of these 2 progenies was unexpected. The other 4 progenies of population 14 x 15 were moderately high to high in strength. Two of these, 14-2 x 15-5 and 14-4 x 15-5 involved intermediate plants of line 14 with high strength plant 15-5. The superior performance of these 2 progenies is not surprising. However, in the other 2 progenies the performance was somewhat higher than expected.

Results with population 14 x 15 illustrate the difficulty encountered in attempting to classify an entire population for strength performance. Although the general level of progenies in this population was high, 2 of the 6 progenies were inferior. As a result it would be misleading to classify population 14 x 15 as high or moderately high in performance.

The intercross progenies 14-2 x 15-2 and 14-2 x 15-4 would not be of value for recurrent selection because of their low variation and mean strength. The remaining 4 progenies of population 14 x 15 should be valuable for use in recurrent selection because of their high mean strength. Of special importance is the number of plants which approach or exceed the mean of the stronger parent in all of the 4 high strength progenies.

The 2 plants of progeny 14-4 x 15-5 and 14-5 x 15-2 which were placed in strength class 4.7 are especially noteworthy. Both of these plants were higher in fiber strength than any plant of the Sea Island parent. These plants were abnormally high in strength and resemble those plants discussed earlier as occurring in F_4 populations 18 and 19. As indicated there, no explanation can be offered for these abnormally high strength plants except that they are found occasionally in this interspecific hybrid. No abnormally high strength plants occurred, however, in the F_4 progenies of any of the F_3 parent plants involved in these 2 intercrosses.

<u>Intercross Population 14 x 18</u>

Five progenies of intercross population 14 x 18, containing from 7 to 19 plants per progeny, were studied (table 4). These 5 progenies involved plants 1, 2, 4 and 5 of F_3 line 14 and plants 1 and 7 of F_3 line 18. A striking feature of the 5 intercrosses in this population is the fact that they differ greatly in fiber strength but all were low in variability, with the number of classes per progeny ranging from 4 to 6. The variation in each progeny was not appreciably greater than that found in the parents. Progenies 14-1 x 18-1 and 14-2 x 18-1 had a strength index mean of 3.17 units, a low strength. Progeny 14-4 x 18-1 had an intermediate strength index of 3.49 units. Progenies 14-5 x 18-1 and 14-5 x 18-7 had high strength means of 3.89 and 3.83 units, respectively.

Of the F_3 plants involved in intercross 14 x 18, plants 2, 4 and 5 of line 14 were classed as intermediate. Plant 1 of F_3 line 18 was intermediate; and plant 7 of line 18 was moderately high in strength (table 3).

The strength index means for intercross progenies 14-1 x 18-1 and 14-2 x 18-1 were low, or 3.17 units in both. Since the parent plants of both progenies had been classified as intermediate in strength, this result was considerably lower than expected. The intermediate strength of progeny 14-4 x 18-1 might have been expected from a combination of intermediate parents. The high mean strength of progenies 14-5 x 18-1 and 14-5 x 18-7 was much higher than expected for progenies which did not involve high strength parent plants.

Intercross progenies 14-1 x 18-1, 14-2 x 18-1 and 14-4 x 18-1 would be rated as inferior because of low strength. Progeny 14-4 x 18-1, although average in mean strength, could be of value in recurrent selection because of its frequency of plants in the Sea Island strength range.

Progenies 14-5 x 18-1 and 14-5 x 18-7 should be suitable for use in recurrent selection because of their high strength and the number of plants having a strength index equal to or above the mean of Sea Island. Thus, as a whole, intercross population 14 x 18 had 3 progenies of value in recurrent selection and 2 progenies that were distinctly inferior in strength.

<u>Intercross Population 14 x 19</u>

Five progenies of intercross population 14 x 19, containing from 8 to 22 plants per progeny, were studied (table 4). These 5 progenies involved plants 1 and 4 of F_4 line 14 and plants 1, 2, 3 and 4 of line 19. The strength range of the intercross progenies varied from 5 to 10 strength index class intervals per progeny. All of the progenies showed a relatively wide degree of variation except 14-1 x 19-4, which had a low degree of variation.

The strength index means of the 5 intercross progenies ranged from 2.98 to 3.77 units, a difference of 0.79 unit. Progenies 14-1 x 19-3 and 14-1 x 19-4 were low in strength, 14-1 x 19-1 and 14-1 x 19-2 were moderately high, and 14-4 x 19-1 was high in strength. Thus, the 5 intercross progenies showed wide difference in strength index means.

The 14 x 19 intercross population had a strength range from 2.5 to 4.9, or 13 class intervals. The strength index mean for the population was 3.42 units.

Of the F_3 plants involved in intercross 14 x 19, plants 1 and 4 of line 14 were intermediate in strength. Plant 1 of line 19 was low, plants 2 and 3 of line 19 were moderately high, and plant 4 of line 19 was high in strength (table 3).

Two of the 5 progenies of intercross 14 x 19, 14-1 x 19-3 and 14-1 x 19-4, had low mean strength. Both of these progenies were lower in strength than expected from the performance of the parent plants involved.

Progeny 14-1 x 19-3 was derived from F_3 parent plants that were classified as intermediate and moderately high, respectively, in strength. The mean strength of this progeny was below that of the weaker F_3 parent plant. The low mean strength (2.98 units) of 14-1 x 19-4 was even more unusual since the parent plants were intermediate and exceptionally high, respectively, in strength. The mean of this progeny was almost 0.50 unit below that of the lower strength F_3 parent. It is highly unusual to have a progeny mean this much below the mean of the lower strength parent.

As pointed out in an earlier section, the F_4 progeny of plant 19-4 contained several plants which were abnormally high in fiber strength, being above the range of the strongest plants of Sea Island. However, the intercross progeny of 14-1 x 19-4 had no abnormally high strength plants. In fact, all plants of this progeny were within the range of the Deltapine 15 parent. It appears probable that this progeny has been labelled erroneously and that the parentage given in table 4 is not correct.

In addition to progeny 14-1 x 19-4, 14-1 x 19-3 was also low in strength. This progeny was derived from an intermediate and a moderately high strength parent, respectively, and was thus lower in strength than expected.

Two progenies, 14-1 x 19-1 and 14-1 x 19-2, were classified as moderately high in strength. Progeny 14-1 x 19-1, which was derived from an intermediate and a low strength parent, had a higher mean strength than expected. Progeny 14-1 x 19-2, which was derived from an intermediate and a moderately high strength parent, had an expected strength performance.

Progeny 14-4 x 19-1 was classified as high in strength. Since the F_3 parents of this progeny were classified as intermediate and low, respectively, in strength, it is surprising that the strength mean of this progeny was so high. The F_4 progenies of F_3 plants 14-4 and 19-1 did not contain any plants above the Sea Island mean. However, the 14-4 x 19-1 progeny contained several such plants. It is probable that, like 14-1 x 19-4, which was mentioned previously, this progeny has been labelled erroneously, and that the parentage given in table 4 is not correct. It is possible that the labels of progenies 14-1 x 19-1 and 14-4 x 19-1 had been interchanged.

Intercross progeny 14-4 x 19-1 should be of great value in recurrent selection because of its high mean strength and frequency of plants equal to and above the Sea Island mean strength. Although progenies 14-1 x 19-1 and 14-1 x 19-2 had only moderately high strength means, both had a high frequency of high strength plants. Therefore, these progenies should have some potential value for further use in recurrent selection. Actually, only one of the intercross progenies of the population, 14-1 x 19-4, would probably have been valuelss for further selection.

Since 4 of the 5 intercross progenies of population 14 x 19 would have been of value for further breeding work, this population could be classified as moderately high in performance.

Intercross Population 15 x 16

Three progenies of intercross population 15 x 16, containing from 6 to 17 plants per progeny, were studied (table 4). These 3 progenies involved plants 2, 3 and 6 of F_3 line 15 and plants 5 and 7 of line 16. The strength range of the intercross progenies varied from 4 to 6 strength class intervals per progeny. Thus the degree of variation within progenies was low and did not exceed, in terms of strength class intervals, that of the Sea Island parent.

The strength index means of the 3 progenies ranged from 3.35 to 4.02 units, a difference of 0.67 unit. One progeny was intermediate in strength, while the other 2 progenies were high in strength. The mean of progeny 15-6 x 16-5 approached that of the Sea Island parent. Thus, there were wide differences in the mean strength of the progenies.

The 15 x 16 intercross population had a strength range from 2.9 to 4.5, or 9 class intervals. The strength index mean for the population was 3.74 units.

Of the F_3 plants involved in intercross 15 x 16, plants 3 and 6 of line 15 were intermediate, and plant 2 of line 15 was moderately high in strength. Plant 5 of line 16 was low and plant 7 of line 16 was moderately high in strength (table 3).

Progeny 15-3 x 16-5 had intermediate mean strength. Since this progeny was derived from a cross of a low strength F_3 parent plant with one that was intermediate, its mean strength was somewhat higher than expected. Progeny 15-2 x 16-7 involved moderately high strength parent plants. Thus, the high strength of this progeny was not unexpected in view of the small size of the progeny. Progeny 15-6 x 16-5 had a very high mean strength which approached that of the Sea Island parent. Since the parent plants were intermediate and low in strength, a progeny with a very high mean of 4.02 units was unexpected. The mean of this progeny was 0.54 unit above that of the stronger F_3 parent. The F_4 progeny of F_3 plant 15-6, although it had an intermediate mean strength, contained some plants above the Sea Island mean. Apparently, F_3 plant 15-6 contained genes for very high fiber strength.

Two of the 3 progenies of population 15 x 16 would be of great value for further recurrent selections. These are progenies 15-2 x 16-7 and 15-6 x 16-5, which had unusually high strength means. The other progeny (15-3 x 16-5), being of only average strength, would be of little value in breeding.

Intercross Population 15 x 17

Only 2 progenies of intercross population 15 x 17, containing from 6 to 8 plants per progeny, were studied (table 4). These 2 progenies involved plants 3 and 5 of F_3 line 15 and plants 5 and 6 of line 17. The strength range of the intercross progenies varied from 5 to 7 class intervals per progeny. Thus the 2 progenies were not highly variable. The strength index means of the 2 progenies were 3.43 and 4.08 units, a difference of 0.65 unit. The mean strength of one progeny was intermediate; while that of the other was very high, being the same as that of Sea Island.

Intercross population 15 x 17 did not have an adequate number of progenies for a reliable evaluation as a population.

Of the F_3 plants involved in intercross 15 x 17, plant 3 of F_3 line 15 was intermediate in strength, while plant 5 of line 15 was high in strength. Plant 5 of line 17 was moderately high and plant 6 of line 17 was high in strength (table 3).

The intermediate mean strength progeny, 15-3 x 17-5, was derived from an intermediate and a moderately high strength parent. The average strength performance of this progeny was therefore expected. The other progeny, 15-5 x 17-6, had very high strength parents. This progeny had a high mean strength which exceeded the mean of the higher strength parent and was equal to that of Sea Island. However, a high strength intercross progeny was expected from 15-5 x 17-6. The F_4 progenies of both F_3 parent plants contained plants above the Sea Island mean strength.

The high mean strength progeny of 15 x 17 population would be of great value for use in further recurrent selection, while the average mean strength progeny should be of some value.

Intercross Population 15 x 18

Four progenies of intercross population 15 x 18, containing from 3 to 18 plants per progeny, were studied (table 4). Progeny 15-6 x 18-5 did not have enough plants for a reliable progeny strength evaluation. The remaining 3 progenies, which were considered, involved plants 1, 3 and 4 of F_3 line 15 and plants 1 and 3 of line 18. The strength range of the intercross progenies varied from 6 to 7 strength class intervals per progeny. No progeny differed greatly from the Sea Island parent in variability.

The strength index means of the 3 intercross progenies varied from 3.48 to 4.14 units, a difference of 0.66 unit. Progeny 15-3 x 18-1 was intermediate, progeny 15-1 x 18-1 was moderately high and progeny 15-4 x 18-3 was unusually high in strength. Thus, the 3 progenies showed wide differences in strength index means.

The 15 x 18 intercross population had a strength range from 2.9 to 4.7, or 10 strength class intervals. Progeny 15-4 x 18-3 had 2 plants above the strength range of the Sea Island parent.

Of the F_3 plants involved in intercross 15 x 18, plant 3 of line 15 had intermediate strength, while plants 1 and 4 of line 15 had moderately high strength. Plant 1 of line 18 had intermediate strength, while plant 3 of line 18 had abnormally high strength (table 3).

Since progeny 15-3 x 18-1 was derived from intermediate strength F_3 parent plants, the intermediate strength of this progeny could have been expected. Progeny 15-1 x 18-1, which involved parents that were moderately high and intermediate, respectively, in strength, had a moderately high mean strength index. Although the progeny mean was slightly above the higher parent mean strength, in general, the progeny performance was as expected.

Intercross progeny 15-4 x 18-3 had an unusually high mean strength of 4.14 units. It also had a surprising number of high strength plants above the Sea Island mean, or 9 plants of the 13 in the progeny. Two of the plants of this progeny were above the strength range of the Sea Island parent and no plants were below this strength range. Progeny 15-4 x 18-3 was derived from parent plants that were moderately high and abnormally high, respectively, in strength. Its performance was not unexpected.

Progeny 15-4 x 18-3 would have a high value for further use in recurrent selection because of its unusually high strength. The moderately high mean strength progeny (15-1 x 18-1) should also be of value. The average mean strength progeny (15-3 x 18-1), which had a high percentage of plants in the Sea Island strength range, might be suitable for breeding work.

The occurrence of plants in intercross progeny 15-4 x 18-3 with abnormally high strength can be accounted for by the fact that parent plant 18-3 contained genes for this condition.

Intercross Population 15 x 19

Seven progenies of intercross population 15 x 19, containing from 4 to 22 plants per progeny, were studied (table 4). These 7 progenies involved plants 1, 2, 3, 5 and 6 of F_3 line 15 and plants 1, 3, 5 and 7 of line 19. The strength range of the intercross progenies varied from 3 to 7 strength index class intervals. Thus the progenies of population

15 x 19 were not highly variable.

The strength index means of the 7 intercross progenies ranged from 3.37 to 3.83 units, a difference of 0.46 unit. Progenies 15-3 x 19-5 and 15-5 x 19-3 were intermediate in mean strength. Progenies 15-2 x 19-3 and 15-3 x 19-3 had moderately high mean strength. Three progenies, 15-1 x 19-1, 15-2 x 19-1 and 15-6 x 19-7 had high mean strength. Thus, the 7 progenies showed wide differences in strength index means.

The 15 x 19 intercross population had a strength range from 2.9 to 4.3, or 8 strength index class intervals. The strength index mean for the population was 3.62 units.

Of the F_3 plants involved in intercross 15 x 19, plants 3 and 6 of line 15 were intermediate in strength, plants 1 and 2 of line 15 were moderately high and plant 5 of line 15 was high in strength. Plant 1 of line 19 was low in strength, plants 5 and 7 of line 19 were intermediate, and plant 3 of line 19 was moderately high in strength (table 3).

Two of the 15 x 19 intercross progenies had intermediate mean strength. One of these was progeny 15-3 x 19-5, which was derived from intermediate strength parent plants and behaved in strength performance as expected. The other intermediate strength progeny, 15-5 x 19-3, had a high and a moderately high strength parent. Therefore, its strength performance was lower than expected, being below that of the lower strength parent plant. However, there were only 4 plants in this progeny. Two of the 15 x 19 intercross progenies were classified as moderately high in strength. Of these 2 progenies, 15-2 x 19-3 had moderately high parent plants, while 15-3 x 19-3 had intermediate and moderately high parent plants, respectively, in strength. Thus, the strength performance of both moderately high strength progenies was expected.

Three of the 15 x 19 intercross progenies were classified as high in strength. Two of these, 15-1 x 19-1 and 15-2 x 19-1 were derived from parent plants that were moderately high and low, respectively, in strength for both progenies. Thus, the progeny performance of these 2 progenies was unexpected, since each of them exceeded the mean of its higher strength parent plant.

Intercross progeny 15-6 x 19-7 had a high mean strength, although it was derived from intermediate strength F_3 parent plants. The unexpected high strength performance of this progeny exceeded the mean of the higher strength F_3 parent plant.

The intercross progenies of intercross population 15 x 19 included 2 that were average, 2 that were moderately high and 3 that were high in mean strength.

Of the 7 intercross progenies of population 15 x 19, the 3 high strength progenies and the 2 moderately high strength progenies had a high frequency of high strength plants. These 5 progenies should be of great value in a recurrent selection breeding program. The 2 average mean strength progenies would be of doubtful value. Thus most of the progenies of this population would be valuable.

<u>Intercross Population 15 x 20</u>

Three progenies of intercross population 15 x 20, containing from 3 to 18 plants per progeny, were studied (table 4). However, progeny 15-3 x 20-8, which contained only 3 plants, was too small to permit any reliable conclusions to be drawn from it. The other 2 intercrosses involved plants 2 and 4 of F_3 line 15 and plants 4 and 5 of F_3 line 20. The degree of strength variation within progenies varied widely. Progeny 15-2 x 20-4 had a relatively wide degree of variation, while the degree of variation within progeny 15-4 x 20-5 was low. The strength index means of the 2 progenies ranged from 3.37 to 3.58, a difference of 0.21 unit. Progeny 15-2 x 20-4, with a mean of 3.37 units, could be classed as intermediate in strength. The other progeny of population 15 x 20 was moderately high in strength.

The 15 x 20 intercross population had a strength range from 2.5 to 3.9, or 8 class intervals. The strength index mean for the population was 3.49 units, or intermediate.

Of the F_3 plants involved in intercross 15 x 20, plants 2 and 4 of F_3 line 15 were classed as moderately high. Plant 5 of line 20 was low, while plant 4 of line 20 was moderately high in strength (table 3).

The parent plants of the average strength progeny 15-2 x 20-4 were both moderately high in strength. Therefore, the intermediate mean of that progeny is somewhat lower than expected. The F_3 parent plants of progeny 15-4 x 20-5 were moderately high and low, respectively, in strength. Thus, the moderately high strength of this progeny could have been expected.

Intercross progeny 15-4 x 20-5 could be of value in recurrent selection because of its moderately high strength and high frequency of high strength plants. Progeny 15-2 x 20-4, although only intermediate in mean strength, could be potentially valuable in recurrent selection because of its high percentage of plants in the strength range of Sea Island.

The value of intercross population 15 x 20 cannot be estimated reliably on the basis of results from only 2 progenies.

Intercross Population 16 x 17

Only 1 progeny of intercross population 16 x 17, containing 18 plants, was studied (table 4). This progeny involved plant 3 of F_3 line 16 and plant 8 of line 17. This progeny showed a moderate degree of variation, ranging in strength from 2.9 to 3.9, or 6 class intervals. The progeny mean was 3.40 strength index units, above average.

Both F_3 parent plants were low in strength (table 3); therefore, the intermediate progeny strength was somewhat higher than would have been expected.

Intercross progeny 16-3 x 17-8 would be of doubtful value because of its intermediate strength and low strength variation.

Intercross Population 16 x 19

Four progenies of intercross population 16 x 19, containing from 9 to 15 plants per progeny, were studied (table 4). These 4 progenies involved plants 5, 6, 7 and 8 of F_3 line 16 and plants 1, 3 and 5 of line 19. The degree of variation within lines was moderately high, or 5 or 6 strength class intervals for each of the 4 progenies. The mean strength indices of the 4 intercross progenies ranged from 3.34 to 3.74 units, a difference of 0.40 unit. One of the 4 progenies, 16-8 x 19-3 was intermediate in strength. Progenies 16-5 x 19-1 and 16-6 x 19-1 were moderately high in strength, with means of 3.56 and 3.54 units, respectively. Progeny 16-7 x 19-5 was high in strength, with a mean of 3.74 units.

The 16 x 19 intercross population had a strength range from 2.9 to 4.3, or 8 class intervals. The population strength index mean was 3.52 units.

Of the F_3 plants involved in intercross 16 x 19, plants 5 and 8 of line 16 were classed as low strength, while plant 6 of line 16 was intermediate, and plant 7 of line 16 was moderately high in strength. Plant 1 of line 19 was low, plant 5 of line 19 was average, and plant 3 of line 19 was moderately high in strength (table 3).

Intercross progeny 16-8 x 19-3 involved a low and a moderately high strength parent plant. The intermediate strength of this progeny was expected. Two of the 4 16 x 19 progenies were moderately high in strength. Of these 2 moderately high strength progenies, 16-5 x 19-1 had low strength parent plants, while 16-6 x 19-1 had a low and intermediate strength parent. Thus, the moderately high strength of both progenies was above the mean of the stronger F_3 parent, and was therefore unexpected. Progeny 16-7 x 19-5 involved moderately high and high strength F_3 parents; therefore the high strength progeny was not expected from this cross. The mean strength of the intercross progeny 16-7 x 19-5 was above that of the stronger F_3 parent.

Progeny 16-7 x 19-5 should be suitable for use in recurrent selection because of its high strength and the frequency of high strength plants. Although they had only moderately high mean strength, progenies 16-5 x 19-1 would be of value because of the high strength plants in their progenies. Progeny 16-8 x 19-3 could be considered inferior because of its intermediate mean and strength range. Population 16 x 19 contained three progenies of value and 1 which was inferior for a breeding program.

Intercross Population 17 x 18

Three progenies of intercross population 17 x 18, containing from 8 to 13 plants per progeny, were studied (table 4). These 3 intercrosses involved plants 6 and 8 of F_3 line 17 and plants 5 and 7 of line 18. The range in variation within progenies was from 5 to 8 strength class intervals. The degree of variation was moderately wide within 17-8 x 18-5 and low in the other progenies. The strength index means for the 3 progenies ranged from 3.46 to 3.69, a difference of only 0.23 unit. Thus, the strength difference between progenies was not great.

The 17 x 18 intercross population had a strength range from 3.1 to 4.5, or 8 class units. The strength index mean for intercross population

17 x 18 was 3.61 units.

Of the F_3 plants involved in intercross 17 x 18, plant 8 of line 17 was classed as low in strength, while plant 6 of line 17 was high in strength. Plant 7 of line 18 was moderately high in strength, while plant 5 of line 18 was very high in strength, being equal to Sea Island (table 3).

Intercross progeny 17-8 x 18-7 involved a low and a moderately high parent plant. As expected, this progeny had an intermediate mean strength. The other 2 of the 3 progenies had moderately high strength index means. Progeny 17-6 x 18-7 had a high and a moderately high strength parent. Therefore, the moderately high strength progeny of this cross could have been expected. Another moderately high strength progeny was 17-8 x 18-5, the F_3 parents of which were low and very high in strength. The moderately high strength performance of this progeny could also have been expected. Thus, all of the intercross progenies of 17 x 18 behaved as expected.

Intercross progenies 17-6 x 18-7 and 17-8 x 18-5 should be valuable in recurrent selection because of their moderately high mean strength and high frequency of high strength parents. Although progeny 17-8 x 18-7 was intermediate in mean strength, it contained a number of plants within the Sea Island range. Therefore, this progeny might be of moderate value in a breeding program.

Intercross Population 17 x 19

Seven progenies of intercross population 17 x 19, containing from 9 to 21 plants per progeny, were studied (table 4). These 7 progenies involved F_3 plants 1, 5, 6 and 8 of line 17 and plants 1, 2, 3, 5 and 7 of line 19. The degree of strength variation within progenies varied widely for the 9 studied. Strength variation within 3 of the 9 progenies was low. These 3 progenies were 17-1 x 19-3, 17-5 x 19-2 and 17-8 x 19-5. There was a relatively wide degree of strength variation within progenies for the other 6 studied, as in 17-6 x 19-5, which ranged from 2.9 to 4.5, or 9 strength class intervals. In population 17 x 19 there were several progenies in which some plants equalled or exceeded the mean strength of Sea Island. Progeny 17-5 x 19-1 had 2 abnormally high strength plants which were above the range of Sea Island.

The strength index means of the seven 17 x 19 intercross progenies ranged from 3.38 to 3.94 units, a difference of 0.56 unit. Three of the 7 progenies were average in mean strength. These were 17-1 x 19-3, with 3.38 units; 17-5 x 19-2, with 3.46 units; and 17-8 x 19-5, with 3.50 strength index units. Progeny 17-6 x 19-7, with a mean of 3.62 units, was moderately high in strength. The remaining 3 progenies were high in strength. These were 17-5 x 19-1, with a mean strength index of 3.94 units' 17-5 x 19-3, with a mean of 3.80 and 17-6 x 19-5 with a mean of 3.71 strength index units.

The 17 x 19 intercross population had a strength range from 2.9 to

4.7, or 10 class intervals. The strength index mean for the population was 3.63 units, or moderately high.

Of the F_3 plants involved in intercross 17 x 19, plants 1 and 8 of line 17 were classed as low in strength, plant 5 of line 17 was moderately high, and plant 6 of line 17 was high in strength. Plant 1 of line 19 was low in strength, plants 5 and 7 were average and plants 2 and 3 of line 19 were moderately high in strength (table 3).

Three of the 9 intercross progenies of intercross population 17 x 19 had average strength index means. Of these progenies, 17-1 x 19-3 had a low and a moderately high strength F_3 parent plant and performed as expected. Progeny 17-5 x 19-2 had moderately high strength parent plants. The performance of this progeny was lower than expected, being below the lower strength F_3 parent. Progeny 17-8 x 19-5, with a low and intermediate strength parent, performed as expected.

One of the progenies, 17-6 x 19-7, gave a moderately high strength performance. The parent plants of this progeny were high and intermediate in strength. Thus, the progeny behaved as expected.

Three progenies had a high strength performance. Progeny 17-5 x 19-1 had a moderately high and a low strength parent. This progeny had a very high mean, which might have been accounted for partly by 2 abnormally high strength plants in the 4.7 strength class interval. The strength performance was higher than expected. Progeny 17-5 x 19-3, which had moderately high strength parents, gave an unexpectedly high performance. Progeny 17-6 x 19-5, which had a high and an intermediately high strength parent, gave an expected high strength performance. Thus, 1 progeny of population 17 x 19 gave a lower strength mean than expected, 2 gave a higher mean, and 4 gave the strength performance that was expected.

As a whole, intercross population 17 x 19 was moderately high in strength. None of the progenies had a mean strength below average. Three of the progeny means were average, 1 was moderately high and 3 were high in strength.

Of the seven progenies of population 17 x 19, four which had moderately high to high means would unquestionably be of value in breeding. One of these progenies contained 2 plants which were approximately 0.10 unit above the highest strength Sea Island plant in strength. Two of the three average mean strength progenies might also be worthwhile because of their plants which approach the Sea Island mean strength.

Intercross Population 17 x 20

Three progenies of intercross population 17 x 20, containing from 3 to 20 plants per progeny, were studied (table 4). The results of progeny 17-1 x 20-8 would not be considered reliable, since it contained only 3 plants. The other 2 progenies involved plants 5 and 8 of F_3 line 17 and plant 8 of line 20. The degree of strength variation was relatively wide in progeny 17-5 x 20-8. In this progeny the strength ranged from 2.7 to

4.5, or 10 strength class intervals. However, in progeny 17-8 x 20-8 the degree of strength variation was lower than that of the parents, or only 3 class intervals. The strength index means of the 17 x 20 intercross progenies were 3.56 and 3.73 units, a difference of only 0.17 unit. Thus, 1 of the progenies was moderately high, while the other was high in strength.

The 2 progenies of population 17 x 20 represent an insufficient number on which to base any reliable conclusions concerning the population.

Of the F_3 plants involved in intercross 17 x 20, plant 8 of line 17 was low in strength and plant 5 of this line was moderately high. Plant 8 of line 20 was moderately high in strength (table 3).

The 2 progenies of population 17 x 20 which were considered in this study were both derived from the moderately high strength F_3 plant 20-8 and performed more or less as expected.

On the basis of mean strength and the frequency of plants in the Sea Island strength range, it appears that the 2 progenies considered here would be of value in recurrent selection. However, because of its high percentage of plants which equal or exceed the Sea Island mean, progeny 17-1 x 20-8 should be of greater value than progeny 17-8 x 20-8.

Intercross Population 18 x 19

Eight progenies of intercross population 18 x 19, containing from 1 to 18 plants, were studied (table 4). Two of these progenies, which contained only 1 plant each, were too small to give reliable results. The 6 remaining progenies involved F_3 plants 1, 5 and 7 of F_3 line 18 and plants 1, 2, 3, and 4 of line 19. The degree of strength variation within progenies ranged from 5 to 8 strength class intervals per progeny. Some of the progenies showed a relatively wide degree of variation, while some had no greater degree of variation than the Deltapine 15 and Sea Island parents. Four plants of this population had an abnormally high strength index which was above the range of the Sea Island parent.

The strength index means of the 3 intercross progenies ranged from 3.65 to 4.20 units, a difference of 0.55 unit. Two of the 6 intercross progenies were moderately high in mean strength. These were progenies 18-7 x 19-2 and 18-7 x 19-3. The remaining 4 progenies were all high in mean strength. There were no low or intermediate mean strength progenies among those evaluated of the 18 x 19 intercross population. Although only 2 strength classes were represented in the 18 x 19 intercross population, there were relatively wide differences in strength index means.

The 18 x 19 intercross population had a strength range from 3.1 to 4.9, or 10 class intervals. The strength index mean for the population was 3.87 units, or high in strength.

Of the F_3 plants involved in intercross 18 x 19, plant 1 of line 18 was intermediate in strength, plant 7 of line 18 was moderately high and plant 5 of line 18 was very high in strength. Plant 1 of line 19 was low in strength, plants 2 and 3 of line 19 were moderately high and plant 4 of line 19 was very high in strength (table 3).

Two of the intercross progenies of intercross population 18 x 19 were moderately high in strength. These progenies, 18-7 x 19-2 and 18-7 x 19-3 were derived from moderately high strength F_3 parent plants. Therefore, their strength performance was as expected.

The remaining 4 intercross progenies of intercross population 18 x 19 were classified as high in strength. Of these 4 progenies, the high mean strength of progeny 18-7 x 19-4, which had moderately high and high strength parents, was expected. The high mean strength of progeny 18-5 x 19-1, which had high and low strength parents, was not expected.

The high strength intercross progenies, 18-1 x 19-1 and 18-1 x 19-3 were unusual in several respects. Both had strength index means higher than Sea Island, and both contained plants which were abnormally high in strength. Furthermore, neither progeny had plants below the strength range of the Sea Island parent.

Progeny 18-1 x 19-3 was derived from an intermediate and a moderately high strength plant. Thus, the strength performance of this progeny was much higher than would have been expected. Surprisingly, the performance of progeny 18-1 x 19-1, which was derived from an intermediate and a moderately high strength plant, was also unexpectedly high. Although the F_4 progeny of F_3 plant 1 of line 18 did not have high strength, the F_4 progenies of other plants of line 18 had unusually high strength (table 3). This was true of the F_4 progenies of F_3 plants 3 and 5 of line 18. In some way this tendency to produce abnormally high strength was transmitted through the intermediate and low strength plants to the progeny. This is shown by the occurrence of high strength plants in both intercross progenies.

However, since the stronger parent of 18-1 x 19-1 was only intermediate in strength, its unusually high strength performance was more unexpected than that of progeny 18-1 x 19-3, the stronger parent of which was moderately high.

The abnormally high strength plants of progenies 18-1 x 19-1 and 18-1 x 19-3 need further investigation in order to determine their value. However, without considering these abnormally high strength plants, it would appear that all of the 6 intercrosses of intercross population 18 x 19 should be superior for use in breeding.

Intercross Population 18 x 20

Six progenies of intercross population 18 x 20, containing from 11 to 24 plants per progeny, were studied (table 4). These 6 progenies involved F_3 plants 1, 3, 5, 7 and 8 of line 18 and plants 3, 4, 7 and 8 of line 20. The degree of strength variation within progenies ranged from 5 to 9 strength class intervals per progeny. There was a relatively wide degree of strength variation within some of the progenies, while others were no more variable than the Sea Island parent.

The strength index means of the six 18 x 20 intercross progenies ranged from 3.35 to 3.98 units, or a difference of 0.63 unit. One of the 6 progenies was average in mean strength. This average strength progeny was 18-8 x 20-8, with a mean of 3.35 units. Three of these progenies were classified as moderately high in strength. These progenies were 18-1 x 20-3, with a mean of 3.65 units, 18-1 x 20-7 with a mean of 3.55 units and 18-5 x 20-4 with a mean of 3.55 units. Two of the progenies were high in mean strength. These high strength progenies were 18-3 x 20-7, with a mean of 3.98 and 18-7 x 20-7, with a mean of 3.93 strength index units. Thus, there was a wide range in mean strength of 18 x 20 intercross progenies.

The 18 x 20 intercross population had a range from 2.7 to 4.5, or 10 strength class intervals. The strength index mean for the population was 3.67 units, or moderately high in strength.

Of the F_3 plants involved in intercross population 18 x 20, plant 1 of line 18 was intermediate in strength, plant 7 of line 18 was moderately high in strength, plant 5 of line 18 was high in strength, and plant 3 of line 18 was abnormally high. Plant 8 of line 18, although used as a parent plant, was not tested for strength as an F_4 progeny. Plant 7 of line 20 was very low in strength, but this classification was based on only 1 plant. Plants 4 and 8 were moderately high, and plant 3 was high in strength (table 3).

Five of the 6 intercross progenies involved an F_3 parent plant that had not been reliably classified. These progenies were 18-1 x 20-3, 18-1 x 20-7, 18-3 x 20-7, 18-7 x 20-7 and 18-8 x 20-8. Of the parents used in these crosses, F_3 plants 20-3 and

20-7 had only 1 plant in F_4 progeny and F_3 plant 18-8 was not tested as an F_4 progeny.

One progeny of intercross population 18 x 20 was intermediate in strength. One parent of this progeny, 18-8 x 20-8, was moderately high in strength, while the strength of the other parent (18-8) was not known since its F_4 progeny was not tested for strength. The expected strength performance of intercross progeny 18-8 x 20-8 consequently could not be determined.

Three progenies of population 18 x 20 were moderately high in strength. Of these, progeny 18-1 x 20-3, which was derived from an intermediate and a high strength parent plant, had the expected strength performance. Progeny 18-1 x 20-7, with an intermediate and a low strength parent, had a higher strength performance than expected. Progeny 18-5 x 20-4, which had a high and a moderately high parent, had approximately the mean strength expected, in view of the small number of plants tested.

Two of the 18 x 20 intercross progenies had high mean strength. One of these progenies, 18-3 x 20-7, which had a high and a low strength parent, had a high mean strength, as expected. The other high strength progeny, 18-7 x 20-7, which had a moderately high and a low strength parent had a much higher mean strength than expected. However, as indicated earlier, the classification of parent plant 20-7 is very uncertain since it was based on a single F_4 progeny plant. In view of this uncertainty no reliable conclusion can be made concerning the lack of agreement between the actual performance of intercross progeny 18-7 x 20-7 and its predicted performance.

Of the intercross progenies of intercross population 18 x 20, only 1 progeny, 18-8 x 20-8, would be classified as inferior for use in recurrent selection. This progeny was only average in mean strength and strength distribution. The remaining 5 progenies would be of high value for use in breeding. Progenies 18-3 x 20-7 and 18-7 x 20-7 would be of special value because of their very high mean strength. Thus, 5 progenies of population 18 x 20 would be valuable, while 1 progeny would not be of value in breeding.

Intercross Population 19 x 20

Six progenies of intercross population 19 x 20, containing from 11 to 23 plants per progeny, were studied (table 4). These 6 progenies involved F_3 plants 1, 2, 3 and 4 of line 19 and plants 2, 7 and 8 of line 20. The strength variation, in terms of class intervals, did not exceed that of the Sea Island parent in 5 of the six 19 x 20 intercross progenies. These progenies having low variation were 19-1 x 20-2, 19-1 x 20-8, 19-2 x 20-7, 19-3 x 20-7 and 19-4 x 20-7. Progeny 19-4 x 20-8, with a range of 9 strength class intervals, had a wider strength variation than any of the other progenies of the 19 x 20 intercross population.

The strength index means of the six 19 x 20 intercross progenies ranged from 3.18 to 4.00, a difference of 0.83 unit. Two of the progenies, 19-2 x 20-7 and 19-3 x 20-7 were low in mean strength, with means of

3.18 and 3.29 units, respectively. Progeny 19-1 x 20-2, which was intermediate in strength, had a mean of 3.39 units. The remaining 3 progenies, 19-1 x 20-8, 19-4 x 20-7 and 19-4 x 20-8, having strength index means of 4.00, 3.95 and 3.99 units, respectively, were very high in mean strength. Thus, there were wide differences in strength index means of the 19 x 20 intercross progenies.

The 19 x 20 intercross population had a strength range from 2.7 to 4.7, or 11 strength class intervals. The population contained 4 plants with strength higher than the highest strength Sea Island plant. The strength index mean for the population was 3.63 units, or moderately high.

Of the F_3 plants involved in intercross 19 x 20, plant 1 of line 19 was classed as low in strength, plants 2 and 3 of line 19 were moderately high and plant 4 of line 19 was high in strength. Plant 7 of line 20 was very low in strength, plant 2 of line 20 was intermediate, and plant 8 of line 20 was moderately high in strength (table 3).

Three of the 6 intercross progenies, 19-2 x 20-7, 19-3 x 20-7 and 19-4 x 20-7, involved an F_3 parent plant that had not been reliably classified (20-7). Consequently, the expected performance of these 3 progenies is too uncertain for use in evaluation.

One of the remaining progenies, 19-1 x 20-2, had a low and intermediate strength parent and behaved as expected. Of the other 2 intercross progenies, 19-1 x 20-8 and 19-4 x 20-8, were both high in mean strength. Progeny 19-1 x 20-8 was derived from low and moderately high strength F_3 parent plants. The mean strength of this progeny was higher than expected. Progeny 19-4 x 20-8 had high and moderately high strength parent plants and performed as expected.

Two of the 3 intercross progenies of intercross population 19 x 20 would be highly valuable in breeding because of their high strength mean and distribution. These progenies are 19-1 x 20-8 and 19-4 x 20-8. The remaining intercross progeny would be inferior in a breeding program because of its low strength mean and distribution. This inferior progeny was 19-1 x 20-2. Thus, in the 19 x 20 intercross population, 2 progenies were valuable and 1 progeny was inferior.

Evaluation of Intercross Progenies

The intercross progenies were rated, with respect to their frequency of high strength plants and strength index means, for their potential value for further use in breeding. A progeny was considered valuable for breeding if at least 25% of the plants in it equalled or exceeded 3.90 strength index units. Some plants which were slightly under this standard were classed as valuable if their strength index mean exceeded 3.60 units.

It was assumed that from heterozygous intercross progenies containing 25% of plants with strength indices of 3.90 units or above it should be possible to obtain by selection lines which have fiber strength equal to Sea Island parent. Of course, for selection to be effective it is essential for the intercross progenies to be heterozygous for fiber strength. It is assumed that virtually all of the intercross progenies were heterozygous to some degree for strength of fiber. Since strength is quantitative and each intercross progeny resulted from crossing two F_3 plants derived from different F_3 lines, it is highly probable that the parent plants involved in the intercrosses were genetically different in all cases, thus leading to heterozygous intercross progenies. In fact, there was concrete evidence indicating that most of the progenies were heterozygous. Even though the number of plants per progeny was small, a majority of them were more variable than the homozygous parents (table 4).

Several of the intercross progenies showed a low strength variation in the frequency distribution (table 4). This might seem to indicate a homozygous condition in those progenies, since their strength range had fewer class intervals than the parents. However, this is a misleading indication in view of the small number of plants per progeny that were tested. Presumably, had the intercross progeny population been as large as the original parent populations, the variation within intercross progenies would have been much greater.

Seventy-nine of the 84 intercross progenies grown in 1958 contained 4 or more plants and were rated on the basis of the above standard. Five progenies did not have enough plants for evaluation. Of the 79 progenies which were evaluated, 43 progenies, or 54%, met the standard of value described earlier. Thus, 54% of the intercross progenies tested for strength appeared to have potential value for obtaining lines with the high fiber strength of Sea Island through selection. These results indicate that in respect to fiber strength, the recurrent selection method had led to a very high fiber strength while still retaining considerable heterozygosity.

Further strength improvement should be possible by selection of high strength plants from the progenies of plants which were evaluated in this study. A large number of plants would be needed in order to get a combination of high fiber strength with other desired characters. It might be concluded that the selection in this first cycle of recurrent selection was worthwhile and that enough genetic variation is present to make further strength improvement by recurrent selection feasible.

Evaluation of Parental F_3 Lines

The intercross progenies which were derived from each of the 8 F_3 lines used in this study were grouped and placed into 4 strength classes based on their strength index means. The designation of the strength classes and the range of strength index means included in each class are given below.

L = low strength progeny with mean below 3.30 strength index units.

I = intermediate strength progeny with mean from 3.31 to 3.50 units.

MH = moderately high strength progeny with mean from 3.51 to 3.70 units.

H = high strength progeny with mean of 3.71 and above.

The progenies derived from each of the 8 F_3 lines are summarized in table 5. For example, there were 11 intercross progenies, containing

Table 5. Relation of 7 F_3 lines in respect to their strength performance in intercross progenies.

F_3 line no.	No. progenies in strength classes*				Total
	L	I	MH	H	
13	3	5	2	1	11
14	6	1	4	5	16
15	4	8	6	9	27
16	-	3	2	3	8
17	-	6	4	5	15
18	2	6	8	10	26
19	4	7	10	15	36
20	3	4	6	6	19

* L = Low strength progeny, mean below 3.30

I = Intermediate strength progeny, 3.31 to 3.50

MH = Moderately high strength progeny, 3.51 to 3.70

H = High strength progeny, above 3.71

4 or more plants each, in which an F_3 plant of line 13 was involved as one of the parents. These 11 progenies were classified in accordance with the system described above, and the results are presented in the first line of table 5.

Several factors may limit somewhat the usefulness of this strength classification. One of these is the fact that only 20 of the 28 possible intercross populations were available for this study. For example, the 11 intercross progenies involving line 13 as one parent did not include all possible combinations with the other 7 lines. Actually, only 4 of these 7 line combinations were available, 13 x 15, 13 x 18, 13 x 19 and 13 x 20. Line 14 was represented by only 3 combinations, 14 x 15, 14 x 18 and 14 x 19. Only 2 of the 8 F_3 lines had all 7 possible combinations represented. These were F_3 lines 15 and 19. The 20 line combinations which were used in obtaining the data in table 5 are listed as intercross populations in table 4.

Among other factors affecting the usefulness of this strength classification is the use of different plants of an F_3 line for the various combinations involving that line. This can be illustrated with line 13 (table 4). Plants 1, 3 and 5 were used in the combinations 13 x 15 and 13 x 18; only plant 1 was used in 13 x 19; and only plant 1 and 5 were used in 13 x 20.

As shown in table 5, the number of intercross progenies derived from a particular F_3 line varied from 8 to 36 progenies per line. Thus, there was a wide variation in the number of intercross progenies derived from the 8 F_3 lines.

As indicated previously in the discussion of the results presented in table 4, there were wide differences among the intercross progenies of the same line combination, or intercross population. Note the differences among the intercross progenies of the line combination 14 x 15 in table 4. However, it was pointed out that there was a general tendency for some line combinations to be superior and others to be inferior. The data in table 5 represent an effort to determine whether there was a general tendency for some of the lines to be superior in their performance in the various hybrid combinations.

Of the 11 progenies derived from F_3 line 13, only 1 was classed as high in strength. Furthermore, 8 of these 11 progenies, or 73%, were intermediate or low in strength. Thus, on the basis of the performance of its intercross progenies, line 13 could be rated as inferior. This agrees with the predicted performance which was based on the low strength performance of F_3 and F_4 progenies of line 13 (tables 2 and 3).

Five F_3 lines could be classed as being alike and intermediate on the basis of the strength of the intercross progenies derived from them. These 5 lines were 14, 15, 16, 17 and 20. In each of these 5 lines approximately one-third of the progenies received a high strength rating. Based on the F_3 and F_4 progeny performance (tables 2 and 3), F_3 line 14 was rated low to intermediate, line 15 was rated moderately high, line 16 was rated low, line 17 was rated intermediate and line 20 was rated low to intermediate in strength. For lines 14, 17 and 20 the performance of intercross progenies agreed with that of the F_3 lines from which they were derived. However, the performance of intercross progenies involving line 15, which was rated as moderately high in strength in F_3 and F_4, was somewhat below that expected. Line 16, which had low strength performance in F_3 and F_4, was somewhat higher in strength in intercross progenies than predicted.

The F_3 lines 18 and 19 had a higher percentage of high strength intercross progenies than did the other 6 F_3 lines. Of the 26 progenies derived from line 18, ten (39%) were high in strength. This F_3 line had moderately high to high strength performance in F_3 and F_4. Thus, the intercross progeny performance of line 18 agreed with that predicted earlier. Of the 36 progenies derived from F_3 line 19, 15 (42%) were higher in strength. Line 19 had moderately high strength performance in F_3 and F_4. Therefore, there was agreement between the intercross strength rating and those of F_3 and F_4.

The intercross strength performance of 6 of the 8 F_3 lines agreed rather closely with the performance of these lines in F_3 and F_4. One line had higher and another had lower strength performance in its intercross progenies than in F_3 and F_4. Thus, in a general way, the strength performance of intercross progenies was related to that of the F_3 lines from which they were derived.

Evaluation of Parental Strength Combinations

As indicated in table 3, F_4 progenies grown from the F_3 plants used in intercrosses varied widely in mean strength of fiber, with some less than 3.00 strength index units and others above 4.00 units. Furthermore, the various intercross progenies tested also differed greatly in mean strength, with 1 as low as 2.98 and 1 as high as 4.20 units (table 4). In view of these wide differences among the F_3 parent plants and also among the hybrid progenies in strength, it should be of interest and value to study the relationship between strength of the parent plants and that of the intercross progenies derived from them. In order to make this study from the large number of F_3 parent plants and the intercross progenies involved, the parents were separated into 4 strength classes, designated low, intermediate, moderately high and high, using the system described in the previous section.

This division of the parent plants into 4 strength classes resulted in 10 possible combinations of the parents based on their strength class. These combinations are low x low, low x intermediate, low x moderately high, low x high, intermediate x intermediate, intermediate x moderately high, intermediate x high, moderately high x moderately high, moderately high x high and high x high. All of the 10 possible combinations were represented among the intercrosses grown in 1958, although some combinations were represented by only 1 to 3 intercross progenies.

The intercross progenies were then separated into the same 4 strength classes, on the basis of their mean strength. The number of intercross progenies derived from each of the 10 parent combinations was determined for each of the intercross progeny strength classes separately. This was done without regard to F_3 line number. For this study, only those F_3 parents in which the F_4 progeny tested contained 4 or more plants were included. Also, only those intercross progenies which had 4 or more plants available were used. After elimination of these 2 bases, there were 67 intercross progenies for which sufficient data were available to provide reasonably reliable results concerning strength of parent plants and of intercross progenies.

The results of classifying these 67 intercross progenies on the basis of strength combination of the parents and strength of the intercrosses themselves are presented in table 6. To illustrate the procedure used in this classification, there were 9 intercross progenies in which 1 F_3 parent plant was low and the other intermediate in strength. As shown in the second line of table 6, 4 of these intercross progenies had intermediate mean strength, 3 were moderately high and 2 were high in mean strength. For convenience, this group of 9 intercross progenies is repeated in line 6 of table 6 under the intermediate x low combination.

The relative frequency of intercross progenies having high mean strength (3.71 or above) was used for evaluation of the various strength combinations in table 6. Because of the repetition of most of the strength combinations in table 6, it is difficult to make comparisons directly from this table. Consequently, for comparisons of relative strength performance among the 10 F_3 parent strength combinations, the following

Table 6. Relation between strength rating of parental F_3 plants and performance of intercross progenies derived from them.

Strength rating of F_3 parents*	No. progenies in strength classes*				
	L	I	MH	H	Total
L x L	-	1	1	-	2
L x I	-	4	3	2	9
L x MH	-	4	2	4	10
L x H	-	1	1	1	3
Total		10	7	7	24
I x L	-	4	3	2	9
I x I	3	3	1	3	10
I x MH	4	3	4	3	14
I x H	-	-	1	3	4
Total	7	10	9	11	37
MH x L	-	4	2	4	10
MH x I	4	3	4	3	14
MH x MH	-	2	3	3	8
MH x H	-	1	2	3	6
Total	4	10	11	13	38
H x L	-	1	1	1	3
H x I	-	-	1	3	4
H x MH	-	1	2	3	6
H x H	-	-	-	1	1
Total	-	2	4	8	14

* L = low strength, mean below 3.30 units.

I = intermediate strength, mean of 3.31 to 3.50 units.

MH = moderately high strength, mean of 3.51 to 3.70.units.

H = high strength, mean above 3.70 units.

scheme showing percentages of high strength progenies for each of the 10 combinations is presented.

Strength ratings of F_3 parents	Per cent of high strength progenies
Low x low	0
Low x intermediate	22
Low x moderately high	40
Low x high	33
Intermediate x intermediate	30
Intermediate x moderately high	21
Intermediate x high	75
Moderately high x moderately high	38
Moderately high x high	50
High x high	100

As indicated in table 6, the low x low F_3 parent strength combination had only 2 progenies and the high x high strength combination had only 1 progeny. Not much emphasis can be placed on the results of these 2 strength combinations because of the low number of intercross progenies involved.

Of the 2 progenies from the low x low combination, 1 had intermediate and the other moderately high strength. It is possible that if more progenies from this combination had been tested, some high as well as low strength ones would have been obtained. However, although the data are meager for this combination, they do indicate that the relative frequency of superior progenies would probably be low from the low x low combination and it would not be a desirable type.

One of the most noticeable features of the results is that all of the combinations, except low x low discussed previously, gave 1 or more intercross progenies with high mean strength. This is shown very strikingly by the fact that 2 of the 9 progenies (22%) from the low x intermediate combination were high in strength.

It is assumed that the 2 high strength intercross progenies from the low x intermediate combination would be as valuable in a cotton breeding program for selection of lines having the fiber strength of Sea Island as the progenies with comparable mean strength that were derived from such combinations as high x high and high x moderately high.

There was a general tendency for the relative frequency of high strength progenies to increase with an increase in fiber strength of the parent plants. The low x low combination had 0 and the low x intermediate had 22% of high strength progenies while moderately high x high and high x high had 50% and 100%, respectively.

This tendency was not entirely consistent, however. There were cases in which combinations having different strength parents gave similar percentages of high strength progenies. Examples are low x moderately high, low x high, intermediate x intermediate and moderately high x moderately high. All 4 of these combinations had 30-40% of high strength progenies. A striking inconsistency is the relatively low percentage of high strength progenies in the intermediate x moderately high combination. Although better than average progenies might have been expected from this combination, only 21% of them were high in strength. The reason for this low strength performance of intermediate x moderately high is not known, but it was probably due to chance.

Whether all of the combinations would be of potential value in a breeding program and which combinations would be most valuable are questions of practical importance. As stated earlier, there were too few progenies tested to evaluate the low x low combination thoroughly, but it appears that this combination would be of doubtful value. The low x intermediate and intermediate x moderately high combinations had only 22 and 21% of high strength progenies, respectively. If considered necessary, even these combinations would be of some potential value. However, the other combinations (except low x low) appeared to be superior to these two and would be preferable to them.

All of the other 7 combinations seemed to be suitable for further breeding work, although there were differences among them in frequency of high strength progenies. Three of the 10 combinations appeared to be outstanding, with 50% or more of high strength progenies. These were intermediate x high, moderately high x high and high x high. All of these outstanding combinations had at least 1 parent in the high strength class.

Thus the 10 parental combinations appeared to fall into 3 general groupings based on performance of their intercross progenies. Combinations involving a low strength parent plant with a parent that was low or intermediate gave a low percentage of superior progenies; combinations involving a high strength parent plant with intermediate, moderately high or high gave a high percentage of superior progenies, though not outstanding. It is assumed that the low frequency for the intermediate x moderately high combination was caused by chance.

The results, summarized in the previous paragraph, suggested a general relationship between strength of an F_3 parent and frequency of high strength progenies in intercrosses. In order to investigate this relationship in more detail, the results in table 6 were reexamined. Twenty-four intercross progenies had low strength F_3 plants as 1 or both parents. Of these 24 progenies 7, or 30%, were classed as high in strength. Thirty-seven intercross progenies had intermediate strength F_3 plants as 1 or both parents. Eleven of these 37 progenies, or 29%, were classed as high in strength. Thirty-eight intercross progenies had moderately high strength F_3 plants as 1 or both parents. Thirteen of these 38 progenies, or 34%, were classed as high in strength. Fourteen intercross progenies had high strength F_3 plants as 1 or both parents. Eight of these 14 progenies, or 57%, were classed as high in strength.

Thus, the frequency of high strength progenies was similar for 3 of the groups—crosses in which 1 parent at least was low, crosses in which 1 parent at least was intermediate and crosses in which 1 parent at least was high in strength were, on the average, much superior to the other groups, with 50% or more of them being high in mean strength.

The percentage of high strength progenies derived from crosses having at least 1 high strength parent plant (57%) was about twice that of progenies from crosses having at least 1 low strength parent. Thus, there appeared to be a definite tendency for high strength F_3 parent plants to produce a much greater percentage of high strength progenies than did low strength F_3 parents.

This tendency of high strength F_3 parent plants to produce a much greater percentage of high strength intercross progenies than did low strength parents might be put to a practical use. Since testing cotton fiber for strength is a tedious and time consuming operation, it would seem desirable to eliminate as much strength testing as possible. This might be accomplished by growing and testing F_4 progenies of the F_3 plants used in intercrosses. On the basis of these F_4 progeny tests, intercross progenies having high or moderately high strength parents could be tested first. In this way the desired number of high strength plants might be found without the necessity of testing a great number of low strength progenies.

According to the results in table 6, the frequency of high strength intercross progenies was much higher than that of low strength ones. Among the 67 progenies in this table, only 7 were classed as low in strength while 23 progenies had high mean strength. This surprising relationship is demonstrated well by the group of combinations in table 6 which had at least 1 parent with low strength. None of the 24 progenies from this type of parent combination was itself low in strength while 7 of these progenies had high strength. In fact, high strength progenies were more frequent than any other class. Only 19 progenies were intermediate and only 18 progenies were moderately high.

This tendency for the frequency of high strength intercross progenies to be higher than that of other strength classes cannot be accounted for by use of more high strength than low strength parent plants in the intercrosses. Actually, there were 8 low strength and 6 high strength plants used as parents. Furthermore, there were 21 of the intercross progenies which involved one of the low strength parent plants compared with only 13 intercross progenies involving 1 of the high strength parent plants. This makes the relationship even more difficult to account for.

The author could not find an explanation to account for the strong tendency for almost all parent combinations to produce a surprisingly high frequency of high strength progenies. Presumably, this tendency would be a distinct advantage in a breeding program.

SUMMARY AND CONCLUSIONS

1. An interspecific cross had been made in an attempt to combine the high fiber strength of Sea Island, Gossypium barbadense, with other desirable characters found in the Deltapine 15 variety, G. hirsutum, of American Upland cotton.

2. Based on performance of F_2 plants in respect to 4 characters, one of which was fiber strength, 51 plants had been selected and progeny tested in F_3.

3. Eight outstanding F_3 lines had been selected on the basis of 4 characters, grown and intercrosses attempted in all possible combinations among them. These 8 lines were given the identifying numbers 13 through 20.

4. The parents, F_4 progenies of all F_3 plants used in intercrosses, and 20 intercross populations which included 84 intercross progenies containing a total of 1023 plants were grown in 1958.

5. In this study the fiber strength for each plant mentioned above was tested with the Pressley strength tester at 1/8-inch gauge.

6. There was a considerable difference in fiber strength between the 2 parents used in the cross.

7. Results of strength tests made in 2 different years, using 2 sampling techniques, indicated that 4 to 7 randomly chosen plants from

each F_3 line provided a reasonably adequate sample of that line. This suggests that the use of 4 to 7 plants per line for intercrossing in recurrent selection would be a reasonably satisfactory procedure.

8. The 8 F_3 lines, as such, varied in fiber strength, with line 18 appearing to be the most outstanding.

9. Based on strength performance of the 8 F_3 lines and of their F_4 progenies, strength classification was consistent for 5 of the 8 F_3 lines and agreed in a general way for the other 3 F_3 lines. Lines designated 13 and 16 were classed as low in strength; line 17 was classed as intermediate; lines 15 and 19 were rated moderately high. Lines 14 and 20 were low to intermediate in the tests and line 18 was rated moderately high to high.

10. For convenience in carrying out this study, 4 strength classifications were set up for the F_3 parent plants and for the intercross progenies derived from them. These classes were designated low, intermediate, moderately high and high. Also for convenience, all hybrid plants derived from crosses between 2 lines, such as 13 x 15, were designated as an intercross population, while the hybrid plants derived from an individual cross between 2 F_3 plants were designated as an intercross progeny.

11. Considerable variation was found among intercross populations in respect to potential value for use in breeding. Some populations, as 13 x 15, had no valuable intercross progenies, while others, as 18 x 19, had all intercross progenies of high value.

12. There were large differences among the 8 F_3 lines in their performance as parents in intercrosses. Some lines gave inferior results as a whole in intercrosses, others gave intermediate hybrid progenies and some produced high strength progenies, in general, in intercrosses.

13. As the basis of general performance in the intercrosses, line 13 was inferior, lines 14, 15, 16, 17 and 20 were intermediate and lines 18 and 19 tended to produce high strength progenies in crosses. Thus, for 6 of the F_3 lines there was close agreement between performance as lines and performance as parents in intercrosses. Lines 15 and 16 showed some disagreement, though not great, between performance as lines and as parents in crosses. Line 15 was rated moderately high as a line but only intermediate as a parent and line 16 was low in strength as a line but intermediate as a parent in crosses.

14. Fifty-four per cent of the intercross progenies tested for strength appeared to have potential value for obtaining lines with the high fiber strength of Sea Island through selection. It could be concluded that selection in the first cycle of recurrent selection was worthwhile. Enough genetic variation was present to make further strength improvement by recurrent selection feasible.

15. Several plants in the intercross progenies were abnormally high in fiber strength, exceeding the strength rating of the highest plant of the Sea Island parent. These plants occurred in 8 of the intercross progenies. The explanation for the occurrence of these abnormally high

strength plants and their potential value in a breeding program were uncertain.

16. Wide differences among intercross progenies of the same intercross population were found.

17. All strength combinations of F_3 parents, except low x low, gave 1 or more intercross progenies with high mean strength.

18. There was a tendency for the relative frequency of high strength progenies to increase with the increase in fiber strength of the parent plants.

19. Crosses which had at least 1 low strength parent had the lowest percentage of high strength progenies.

20. Crosses having at least 1 parent which was intermediate or moderately high gave an intermediate frequency of high strength progenies.

21. Crosses which had at least 1 high strength parent gave the highest percentage of high strength progenies.

22. Three of the 10 possible strength combinations of F_3 parent plants produced 50% or more high strength progenies. All 3 of these combinations had at least 1 parent in the high strength class.

23. There was a marked tendency for all parent combinations to produce a high frequency of intercross progenies with high mean strength.

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AUTOBIOGRAPHY

John Hubert Massey, the son of George D. and Iona P. Massey, was born at Homer, Georgia, on September 7, 1916.

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Major Field: Agronomy

Title of Thesis: The Effect of Recurrent Selection on Fiber Strength in an Interspecific Cross of Cotton

Approved:

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